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A Model-Based Optimization Plan for the Naval Helicopter Training Program

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June 2011

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FY2010 presented unique challenges to the Department of Defense and specifically in the Department of the Navy, with the call to ensure that a 1% to 3% real growth is realized through a “tail to tooth” reappropriation of future funds for the continuation of innovations and combat operations. The naval aviation training program, under the management of the Chief of Naval Air Training (CNATRA), is on the tail end of this analogy, indirectly supporting combat operations through the training of student naval aviators (SNAs) from the Navy, Marine Corps, and Coast Guard services with training offered for limited number of students from the Air Force and foreign nations.

The purpose of this project is to model the naval aviation helicopter pilot training program as a supply chain with the output of one stage of production providing the input of the next. Batch arrivals of selected naval aviators, pooling between stages, attritions, and squadron utilization rates combine to make this problem a complex model to quantify. The proposed model accounts for above mentioned factors and is validated through historical data and allows hypothetical student pooling scenarios to be tested and analyzed.

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A MODEL-BASED OPTIMIZATION PLAN
FOR THE NAVAL HELICOPTER TRAINING PROGRAM

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Submitted in partial fulfillment of the requirements for the degree of

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LIST OF ACRONYMS AND ABBREVIATIONS

1LT	First Lieutenant
2LT	Second Lieutenant
AIM	Aeronautical Information Manual
API	Aviation Preflight Indoctrination
ATS	Aviation Training School
ATSB	Aviation Test Selection Battery
BAH	Basic Allowance for Housing
BAS	Basic Allowance for Substance
CFI	Certified Flight Instructor
CNATRA	Chief Naval Air Training
CPT	Cockpit Procedures Trainer
CV	Coefficient of Variation
DoD	Department of Defense
DON	Department of the Navy
DOR	Drop on Request
ENS	Ensign
EOQ	Economic Order Quantity
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FF	Flight Failure
FRS	Fleet Replacement Squadron
GPA	Grade Point Average
HHG	Household Goods
IFS	Introductory Flight Screening
LT	Lieutenant
MCB	Marine Corps Base
MILPERS	Military Personnel

NAS	Naval Air Station
NASC	Naval Aviation Schools Command
NATC	Naval Aviation Training Command
NFO	Naval Flight Officer
NOMI	Naval Operational Medical Institute
NROTC	Naval Reserve Officer Training Corps
OCS	Officer Candidate School
O&M	Operational & Maintenance
PCS	Permanent Change of Station
PTR	Pilot Training Rate
RM	Raw Materials
SECDEF	Secretary of Defense
SIM	Simulator
SNA	Student Naval Aviator
SNFO	Student Naval Flight Officer
TBS	The Basic School
TLE	Temporary Lodging Expense
TTT	Time to Train
USNA	United States Naval Academy
WIP	Work in Process

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First and foremost, we would like to thank our wives and families, both here in Monterey and overseas in Brisbane, who continuously supported and encouraged us throughout this project. They are the reason we are here and the reason we consistently push ourselves to grow and expand our horizons. We would like to give thanks Dr. Uday Apte and Dr. John Khawam for their guidance, patience, and mentoring throughout the entirety of this project. Their inspiration and experiences in operations management and in academic writing were instrumental in keeping us on the task at hand and enabling us to achieve our degree. Finally, we would like to give special thanks to all the instructors and staff at the Naval Postgraduate School (NPS). The last 18 months has been a fast and furious learning experience but the professionalism and dedication by the faculty was evident and is one of the reasons NPS stands apart among other academic institutions.

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I. INTRODUCTION

A. BACKGROUND

The history of the U.S. Navy is rich in tradition. The Continental Navy was founded on Friday, October 13, 1775, which preceded the nation's declaration of independence by nine months, with the decision to purchase and retrofit two sailing vessels (Love, 1992, p. 23). Although this fledgling fleet did not directly challenge the British dominance of the seas, the Continental Navy conducted privateer operations to "raid commerce and attack the transports that supplied British forces in North America" (National History & History Command, 2010).

Over one hundred and twenty years later, the Navy entered a new dimension of fighting. The Department of Navy's (DON) interests in aviation began in 1898, well before the first successful flight by Orville Wright at Kitty Hawk, NC in 1903. Seven years later, in December 1910, LT Theodore Ellyson was assigned to North Island, CA, to train under the guidance of aviation pioneer Glenn Curtiss and, in 1911, would start a new phase in naval history as "Naval Aviator Number One" (California Military Museum, 2010).

Since the birth of naval aviation, aircraft and techniques have become increasingly complex, thus requiring more in-depth training. The Naval Aviation Training Command (NATC) was established to manage these various programs within a single command structure. From naval aviation's humble beginning with the training of a single student naval aviator (SNA), NATC, today, consists of the training of over 1,500 Navy, Marine Corps and Coast Guard pilots and naval flight officers (NFOs) annually in addition to 155 Air Force pilots and more than 100 pilots and flight officers from 10 allied countries of Italy, Norway, Germany, Spain, Denmark, Saudi Arabia, Brazil, France, Singapore and India (CNATRA, 2010). Operating from five separate locations of NAS Pensacola, FL, NAS Whiting Field FL, NAS Meridian MS, NAS Corpus Christi

TX, and NAS Kingsville TX, the NATC, as a whole, can be considered a unique and complex, supply-chain consisting of five training air wings, 17 training squadrons, and 13 aircraft models (CNATRA, 2010).

B. PURPOSE

FY2010 presented unique challenges to the Department of Defense (DoD), and specifically in the Department of the Navy (DON). Growth of defense spending is not sustainable in times of recession and increasing national debt. The Secretary of Defense (SECDEF), Robert Gates, gave specific direction to the DoD as a whole as it prepared for FY2012 budget. In May 2010, the SECDEF directed the "military services, the Joint Staff, the major functional and regional commands, and the civilian side of the Pentagon to take a hard unsparing look at how they operate—in substance and style alike (Gates, 2010)." In this challenge, the line was drawn to realize a 1% to 3% real growth through a "tail to tooth" reappropriation of future funds for the continuation of innovations and combat operations. SECDEF gave further direction on how to achieve this goal. In the same speech, he stated, "the goal is to cut our overhead costs and to transfer those savings to force structure and modernization within the programmed budget" (Gates, 2010). Furthermore, "these savings must stem from root-and-branch changes that can be sustained and added to over time. Simply taking a few percent off the top of everything on a one-time basis will not do" (Gates, 2010).

Doing more with less is not a sustainable business strategy. However, identified cost savings may be found by recognizing inefficiencies within a system or a process. By utilizing good business practices and applying them to military organizations, as applicable, such cost savings may be identified. Among military organizations, the Naval Aviation Training Command (NATC), with one of its functions being to train student aviators and flight officers, can be framed using such business practices found in supply chain models.

C. RESEARCH OBJECTIVES

The main research objective of this project is to build a model of the naval helicopter-training program as a type of supply-chain in order to identify and optimize overall training costs. This will be accomplished through the following.

- Formulation of a linear programming model of the naval aviation helicopter pilot training process
- Validation of the resultant model
- Utilization of the model to optimize the number of students entering the program and advancing to the next stage in training

D. SCOPE

The entirety of this program accounts for students from the Navy, Marine Corps, Air Force and Coast Guard, as well as students from 10 allied nations. Two programs exist, one for student pilots and one for student flight officers. Navy and Marine Corps pilots are commonly referred to as Student Naval Aviators (SNAs) and flight officers referred to as Student Naval Flight Officers (SNFOs). SNAs and SNFOs begin their aviation careers as newly appointed Ensigns (ENS) and Second Lieutenants (2LT) coming from various commissioning sources.

Their aviation training begins with an Introductory Flight Screening (IFS) and Aviation Preflight Indoctrination (API). Upon completion of these two programs, the SNAs and SNFOs split into separate training programs. SNAs continue with primary training flying a common type/model aircraft of the T-34C. Upon graduation of primary training, platform selection is determined and the SNAs split into one of five pipelines of intermediate jet, advanced E–6, advanced maritime, intermediate tilt-rotor and advanced rotary. The intermediate jet pipeline is further split between the advanced Strike and E2/C2 at a later point to finish with a total of six separate pilot pipelines. This process is depicted in Figure 1.

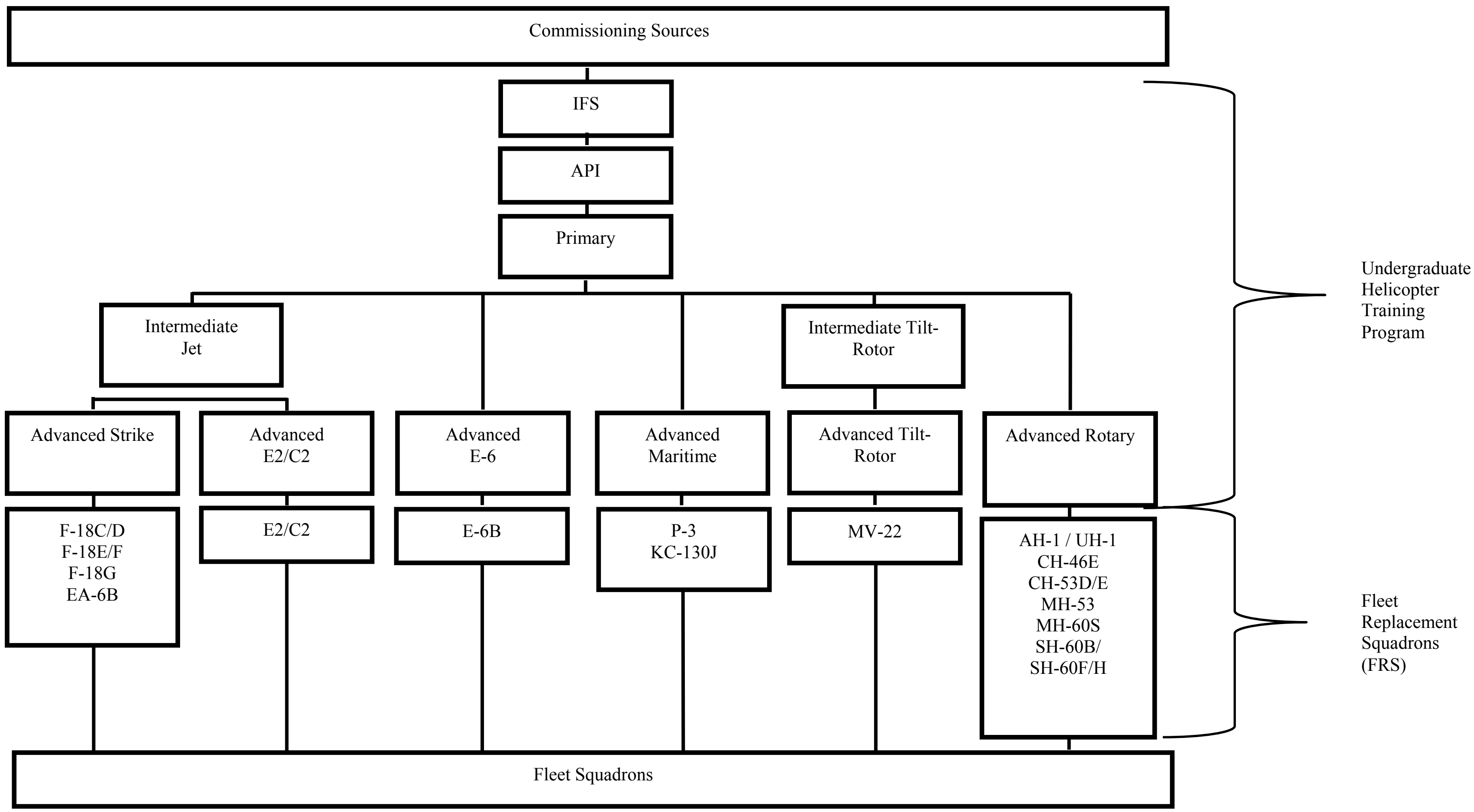

Figure 1. Student Naval Aviator (SNA) Training Pipeline (From Chief Naval Air Training Command (CNATRA))

Due to the complexity with the common phases with the SNA program involving six pipelines, in addition to the Naval Flight Officer (NFO) pipeline, the focus of this project has been narrowed specifically to that of the Navy and Marine Corps student naval aviators within the undergraduate naval helicopter-training program. Historically, this grouping represents the largest concentration in type of students within the overall aviation-training pipeline comprising, on average, 35.9% of the total student loading among the six pilot and one NFO pipelines, as depicted in Figure 2, Department of Navy Operation & Maintenance (O&M) budgetary data FY2001 through FY2010, (Assistant Secretary of the Navy, 2001–2010). However, the resultant model constructed in this project can be easily adjusted, as necessary, to account for other services' student aviators in different training pipelines.

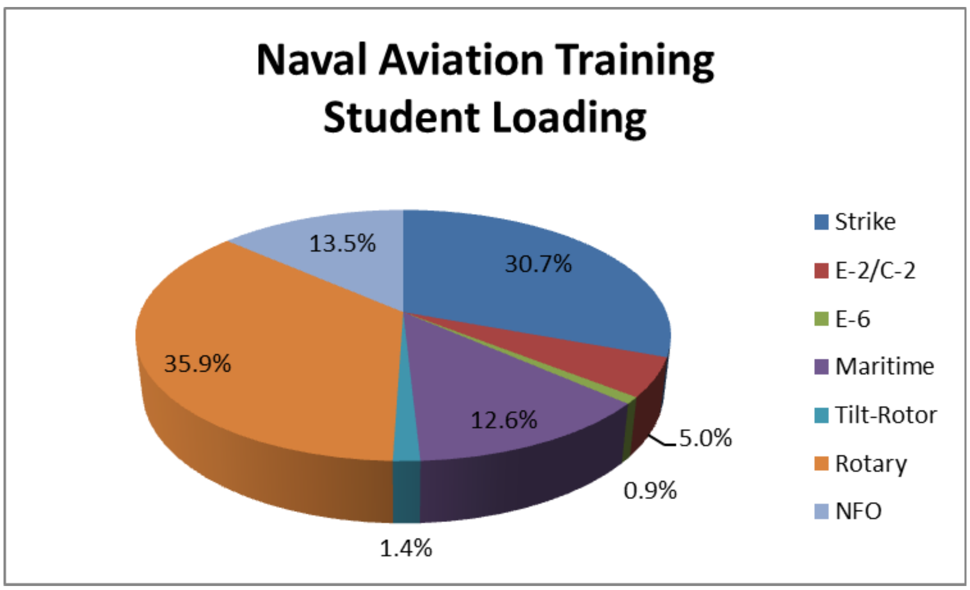

Figure 2. Naval Aviation Training Historical Student Loads (From Assistant Secretary of the Navy, 2001–2010).

E. RESEARCH METHODOLOGY

The helicopter-training pipeline can be framed in terms of a supply-chain model. Customers (i.e., operational fleet squadrons) project the future need for winged pilots qualified in a particular type/model of aircraft. This request must be scheduled and appropriate steps taken approximately two years in advance, which is the average cycle time of the training process from beginning to the end.

Upon receiving the order request of the customer, suppliers (i.e., commissioning sources) provide the necessary raw materials (i.e., student naval aviators). This amount includes additional students required to compensate for projected attrition rates of students not completing the program due to either drop on requests (DORs) or failing grades. Students that complete the undergraduate helicopter pilot training program are queued in "pools" throughout the pipeline. This process consists of training stages to include the Introductory Flight Screening (IFS), Aviation Preflight Indoctrination (API), Primary Flight Training, and Advanced Rotary Flight Training. Differing transfer costs exist between the stages depending on time spent in the queue and any necessary permanent change of station (PCS). After graduating the undergraduate helicopter pilot training program, the newly winged pilots continue their training at the Fleet Replacement Squadrons (FRS). The FRS will further customize the student helicopter pilots, training them in the particular type/model as originally requested by the fleet squadron. FRS training is not covered within the scope of this paper.

From this framing, a simple nine-stage linear programming model will be formulated using Microsoft Excel solver. Decision variables will be based on the number of students entering the program at a particular time period, staying in the same stage from one period to the next, advancing through the program to the next stage or leaving the program through attrition. The objective function will be formulated to minimize costs throughout the entirety of the undergraduate helicopter-training program and constraints will be formulated to take into account fleet squadron demands, capacities of

the various phases, and the supply chaining of the student progression. The model will be based on literature review of publications and procedures, historical data, and assumptions. The overall research methodology consists of the following steps.

- Conducting a literature review and collecting data in the form of historical reports, briefs and presentations
- Defining the process of the naval helicopter training program through an examination of collected data and review of literature
- Formulating a simple linear programming model on the naval undergraduate helicopter training process
- Validating the model using real and hypothetical data
- Utilizing the model to optimize the number of students entering the program and advancing to the next stage in training
- Providing recommendations based on analysis of results of computational experimentation

F. PROJECT ORGANIZATION

The organization of the project is as follows.

Chapter I both introduces the purpose and topic of the paper, giving the reader a brief background of the beginnings of the naval aviation-training program. This chapter also presents the objectives of the paper and defines its scope.

Chapter II describes the helicopter pilot training process, in detail, within the framework of a supply-chain model and calculates variable transfer costs, holding costs and training costs inherent in the system that are used in formulating the optimization model.

Chapter III determines the decision variables that the model is required to solve, formulates an objective function to minimize overall program costs and states constraints necessary for the creation of a simple linear programming model. Microsoft Excel will be utilized to construct a model based on these building blocks and previously calculated variable costs.

Chapter IV covers the conduct of computational experimentation. Real and hypothetical data will be used to validate the model. Various student-loading scenarios will be set up utilizing Microsoft Excel and simulated through multiple runs of each scenario using Microsoft Visual Basic. Student loading scenarios will be balanced and analyzed against time and cost tradeoffs.

Chapter V presents conclusions based on the modeling, simulation and analysis of the process. Recommendations are presented that may be applied to future pilot training program execution strategies. Areas requiring further studies on this subject will be identified.

II. NAVAL HELICOPTER PILOT TRAINING PROCESS

A. BASIC SUPPLY CHAIN

In this chapter, the helicopter pilot training process is described, in detail, within the framework of a supply chain model. Supply chain management consists of five main decision areas (Vob & Woodruff, 2006, p. 4).

1. Strategy
2. Major Resources Capacity Planning
3. Tactical Production Planning
4. Scheduling
5. Execution and Feedback

This paper will focus on Tactical Production Planning, Scheduling and Execution and Feedback. Strategy and Major Resources Capacity Planning involve long-range decision making, which falls outside the scope of this paper. This model recognizes the entire helicopter pilot training process, from beginning to end, as a single unified production process where the output of one stage acts as the input to the next. In the undergraduate helicopter supply chain, SNAs flow through nine different stages, achieving higher and higher levels of training.

B. HELICOPTER PILOT TRAINING SUPPLY CHAIN

As discussed in Chapter I, the majority of student naval aviators (SNAs) within the Navy's pilot training program are in the helicopter-training pipeline. The paper will briefly describe the fleet squadrons, commissioning sources and fleet replacement squadrons (FRS) roles within the overall supply chain. However, the main focus of this paper will be on that of the undergraduate helicopter training program with students entering A-Pool at the beginning of the program and leaving E-Pool at the completion of the program. This supply chain model is depicted in Figure 3.

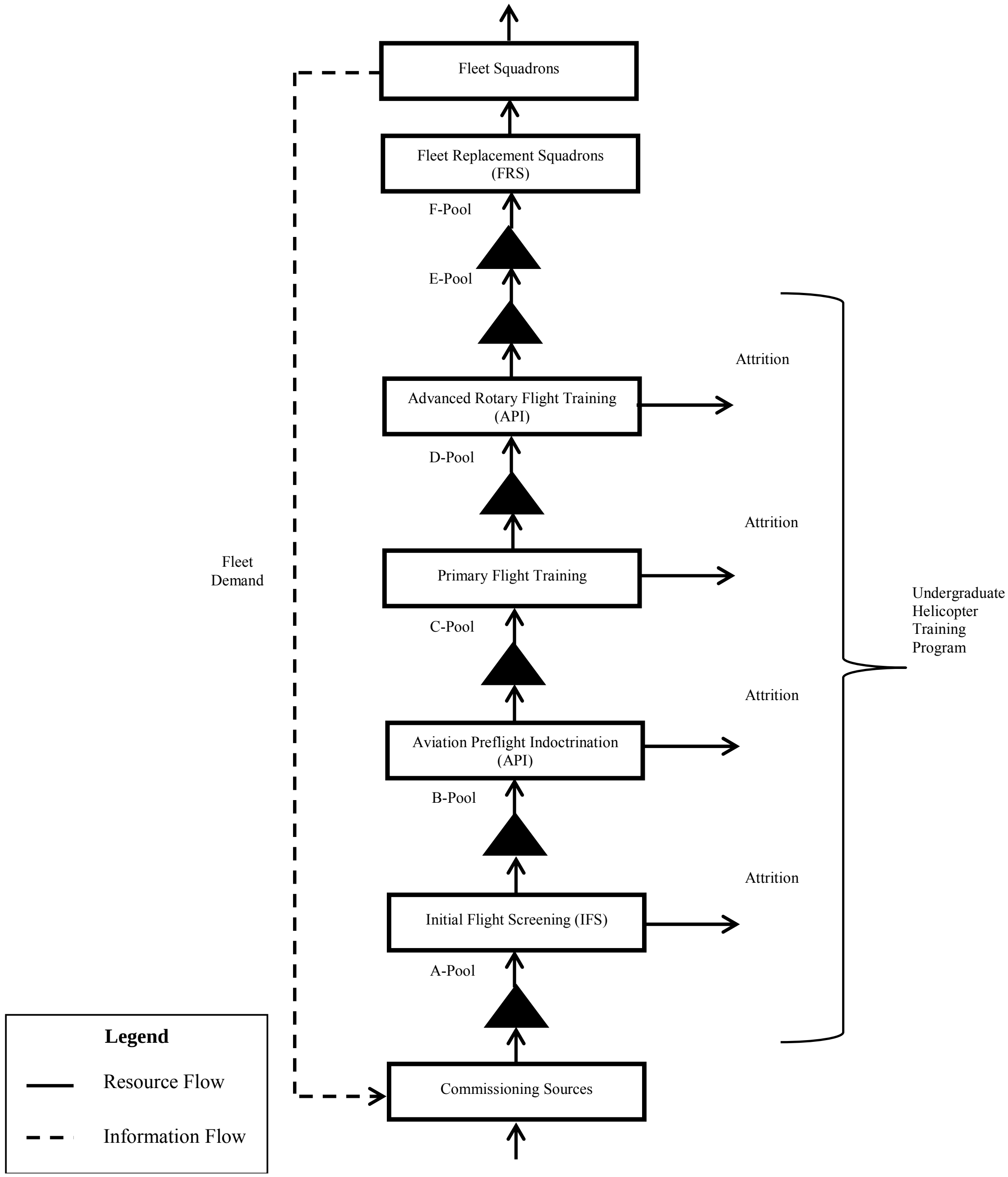

Figure 3. Helicopter Pilot Training Supply Chain (From Chief, Naval Air Training (CNATRA))

By describing the helicopter pilot training as a supply chain it can be used as a management tool to meet customer demands. Meeting customer demand is a priority, but it must be achieved by the most efficient means while meeting minimum helicopter pilot

qualification requirements. At any time when demand is increased in the supply chain and additional resources are not added to the production process, the queue times will increase, unless there is a lowering of quality. As a result, this may lead to additional cost to the government in the future due to under qualified pilots in the operational squadrons.

In the situation where there is a sudden increase in the demand for helicopter pilots, the quick answer is not to arbitrarily add SNA at the beginning of the training process or lower the qualification requirements. Managers can review their helicopter pilot training supply chain to analyze the holding pools to see if they have enough safety stock and if the training stages have enough resources to meet the increased demand without the addition of resources.

The helicopter training supply chain is a PROCESS built on four unique STAGES that include Initial Flight Screening (IFS), Aviation Preflight Indoctrination (API), Primary Flight Training and Advanced Helicopter Training. The STAGES are then divided into specific training PHASES that are tailored to each STAGES' syllabus. PHASES consist of individual ACTIVITIES, such as a flight, simulator event or an academic class. An example of a simplified two-stage process is depicted in Figure 4.

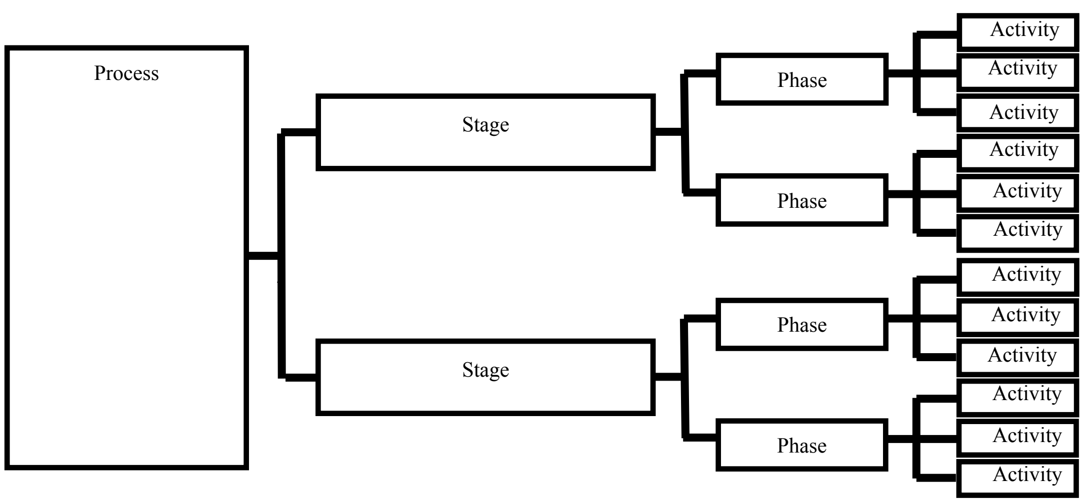

Figure 4. Process Components

The helicopter pilot training phase uses flexible scheduling to reduce time to train. Flexible scheduling is a means to plan phases to overcome unknown variables, such as weather, maintenance and other factors that cannot be anticipated. Due to these unknowns affecting scheduling of various phases, a generic schedule of the four stages is built based on the syllabus of each stage.

Program costs associated with this process are calculated based on composite costs of personnel and cost per flight hour of associated training. Costs associated with management of the squadron are considered sunk costs; this includes instructors, facilities and basic administration. Costs of cockpit procedure trainers (CPTs) and simulators (SIM) are part of the pilot training syllabus under the management of Raytheon, a civilian contractor, are also considered sunk costs. Any attrition is assumed to occur at the end of the particular stage with costs calculated as if the student completed the entire stage. However, Drop on Requests (DORs) from students that choose voluntarily to end training and Flight Failures (FF) from failures of academics, ground events or flight events may occur in any phase of training. Costs associated with student attrition affect costs per student as a whole.

1. Stage 12: Fleet Squadrons (Customers)

The helicopter pilot supply chain begins and ends with the operational fleet squadrons. Pilots qualified in a particular type/model aircraft (i.e., finished products) are requested approximately two years in advance by the various fleet squadrons (i.e., customers). These dates are based on departure or "rotation" dates of pilots within the fleet squadrons who depart to continue their progression through the aviation career track. From this initial request, the number of students required in the training program are scheduled and documented within the Department of the Navy Operations & Maintenance (O&M) future budgets. This process acts to reduce the bull-whip effect through direct communications resulting in a typical push-pull supply chain model.

Changes in requests from the time an order is placed to the time of delivery results in either cutting back the number of students initially assigned to the naval

aviation training program or through the increase of attrition rates for a specific stage. Attritions due to changes in policy are usually made early in the training program to minimize costs of training. This was seen in FY2005, when retiring of aircraft platforms from the naval inventory resulted in the training program attrition rates of Aviation Preflight Indoctrination (API) from 2% to 50% (Assistant Secretary of the Navy, 2001–2010). While allowing fleet squadrons to maintain the required number of pilots, had the added benefit in that, it resulted in an increase of attrition rates early in the program resulted in a reduction of attrition rates later in the training pipeline with student attrition rates for naval helicopter pilots dropping to 0.5 percent. Historical attrition rates for the naval aviation-training program, of which the helicopter-training pipeline is a subset, are depicted in Figure 5, Department of Navy Operation & Maintenance (O&M) budgetary data FY2001 through FY2010 (Assistant Secretary of the Navy, 2001–2010).

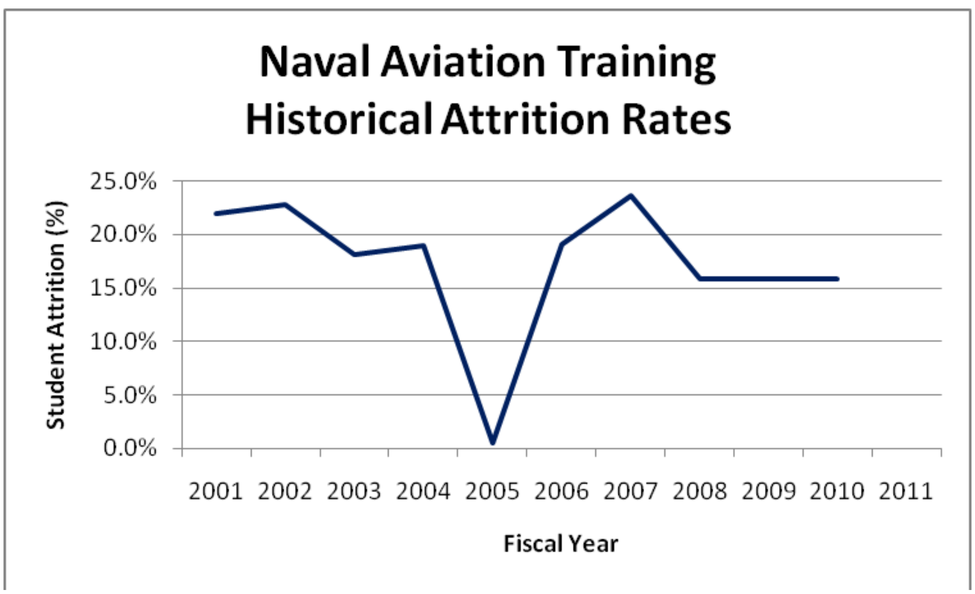

Figure 5. Naval Aviation Training Historical Attrition Rates (From Assistant Secretary of the Navy, 2001–2010)

2. Stage 0: Commissioning Sources (Suppliers)

The commissioning sources consisting of the United States Naval Academy (USNA), Naval Reserve Officer Training Corps (NROTC) and Officer Candidate School

(OCS) provide the students (i.e., raw materials) to the helicopter pilot training program. At the commissioning source, control systems are established to screen applicants based on minimum acceptable levels of vision, academic grade point average (GPA) and the Aviation Test Selection Battery (ATSB). Students are commissioned as Naval or Marine Corps Officers after graduation or completion of OCS. NROTC and USNA students graduate in two main batches, the primary batch occurring in the summer and the secondary batch occurring in the winter. OCS class completion occurs throughout the year. The number of students provided by the various commissioning source for the flight-training program include additional students necessary to adjust for projected attrition rates based on historical numbers. Historical numbers of student aviators assigned to and completing the helicopter pilot training program are depicted in Figure 6, Department of Navy Operation & Maintenance (O&M) budgetary data FY2001 through FY2010 (Assistant Secretary of the Navy, 2001–2010).

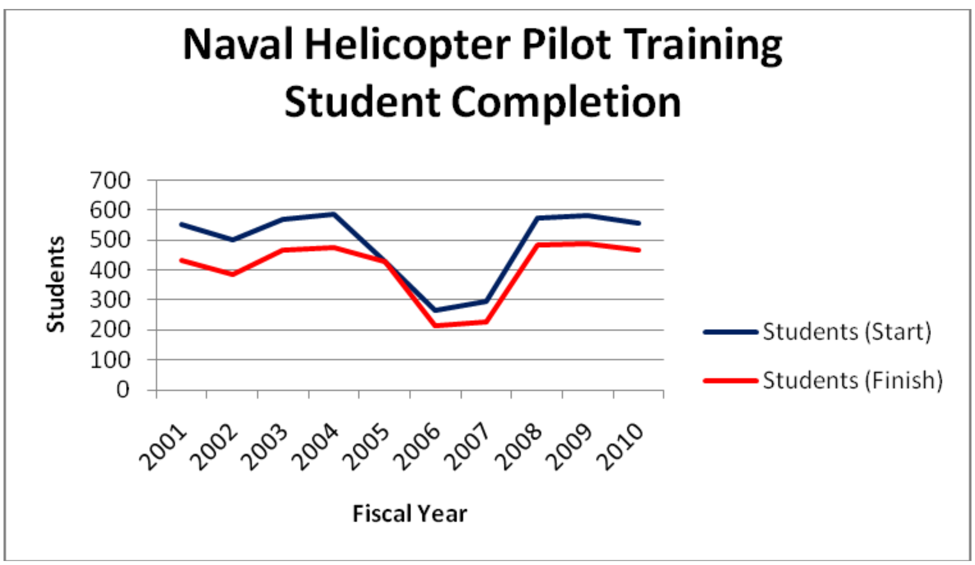

Figure 6. Naval Helicopter Pilot Training Student Completion (From Assistant Secretary of the Navy, 2001–2010)

3. Stage 1: A-Pool

After commissioning, Navy Ensigns (ENS) arrive at NAS Pensacola and enter the first of many queues awaiting the start of IFS training. The first queue is named, "A-Pool." Marine Corps Second Lieutenants (2LT) first attend "The Basic School" (TBS) at Marine Corps Base (MCB) Quantico, VA for six months prior to starting A-Pool. Permanent changes of station (PCS) costs for moving students from the various commissioning sources and TBS to NAS Pensacola to begin the helicopter pilot training program are considered sunk costs. Moves from commissioning sources to the first duty station occur regardless of designator. Daily holding costs of personnel assigned to A-Pool are calculated in Table 10 found in Appendix A. This results in a biweekly variable cost of $2,605 for students held in A-Pool.

4. Stage 2: Introductory Flight Screening (IFS)

The IFS stage was included in 2003 as an extra stage in the naval aviation training program to insert an additional management control system. IFS was designed to reduce overall attrition rates due to Drop on Requests (DOR) and Flight Failures (FF) occurring later in the program by identifying early SNAs and SNFOs who lack determination, motivation and aeronautical adaptability required to succeed in later stages of flight (OPNAV, 2003, p. 1). The IFS stage of training is conducted at one of five select civilian flight schools among four airports in the Pensacola area to include the airports of Pensacola, Milton, Gulf Shores and Mobile. The IFS stage begins with completion of prerequisites necessary to begin training. These prerequisites include medical physicals to ensure physical standards are met for both the Naval Operational Medical Institute (NOMI), as well as Federal Aviation Administration (FAA) regulations to determine any condition that may preclude the start of flight training. Required military specific physical fitness assessments and swim qualifications are also validated and anthropometric checks are conducted to ensure that the student will fit properly in the cockpit, dependent on the type of aircraft that is used. These prerequisites are accomplished during A-Pool.

IFS pilot training is built upon the Jeppesen Private Pilot Syllabus, considered the standard of private pilot courses in civilian flight training (CNATRA, 2007, p. 5). This syllabus consists of three ground school stages and two flight phases resulting in 25 hours of flight time (CNATRA, 2007, p. 16). To maximize the value of each flight hour, a minimum of 30 minutes for prebrief and 30 minutes for postbrief shall be provided on all flights (20 hours total) (CNATRA, 2007, p. 9). Table 13 found in Appendix B depicts the IFS pilot training syllabus. SNAs are mandated to complete IFS training within 50 calendar days of the date of registration (CNATRA, 2007, p. 11). Average program cost for IFS training is $3,760. It is calculated from flight school training costs depicted in Table 1 and syllabus events contained in Table 13 Appendix B. SNAs must successfully pass the Jeppesen Stage exams and the FAA written exam with at least a grade of 80% and must solo within 15 flights (CNATRA, 2007, p. 14). At program completion, 24 to 25 flight hours are completed within the 50 days of enrollment (i.e., four time periods) (CNATRA, 2007, p. 14). Attrition within the program has historically been 4.5% due to DOR and FF (E. Lashua, personal communication, January 18, 2011).

Table 1. Training Costs: Introductory Flight Screening (IFS) (From AMS Aviation at http://www.flymilton.com; Pensacola Aviation at http://www.pensacolaaviation.com; Ferguson Aviation Academy at http://www.fergusonairport.com; Flight Training Mobile at http://www.flyftm.com

Item / Training	Gulf Shores	Milton	Mobile	Pensacola
Flight Equipment & Headset	$400	$400	$400	$400
Ground Instruction	$30	8*	$50	$30
Preflight / Postflight Instruction	$30	$35	$50	$30
Aircraft Rental	$115	$99	$130	$145
Flight Instruction	$30	$30	$50	$30
Check Flights	$30	$30	$55	$30

* Students conducting flight training in Milton are charged fixed fee of $250 for 30 hours of ground training.

Program costs include equipment, ground instruction and flight instruction. SNAs are required to fly in the most economical aircraft (CNATRA, 2007, p. 8). In Pensacola,

these rental rates are listed for fueled aircraft and vary among flight schools. Personnel holding costs are also relevant in this program and are similar to the rates of A-Pool. Composite holding costs are calculated in Table 13 in Appendix A and is calculated resulting in a biweekly variable holding cost of $2,605.

5. Stage 3: B-Pool

Upon completion of IFS training, all students remain at Pensacola, FL and enter the next queue, B-Pool, while awaiting the next stage of training, API. Costs associated with this pool are comprised solely of personnel costs as shown in Table 13 in Appendix A. This results in a biweekly variable cost of $2,605 for each student held in B-Pool.

6. Stage 4: Aviation Preflight Indoctrination (API)

API is a course under the Naval Aviation Schools Command (NASC) Aviation Training School (ATS) department, consisting of three phases: 1) Administration (week 0); 2) Academic ground school teaching the basics of aerodynamics weather, navigation, engines, flight rules and regulations and water survival (weeks 1–4); and 3) NOMI training involving additional water survival, altitude chamber, emergency aircraft egress training, and physiology (weeks 5–6) encompassing seven weeks (i.e., four time periods) (Dixey, 2006. pp. 12–17). Training costs for this stage is considered a sunk cost due to its fixed nature. The variable costs per student associated with this program are comprised of composite personnel holding costs as calculated in Table 10 in Appendix A. This results in a calculated biweekly holding cost for each student of $2,605. Attrition within the program is historically 3.3% due to DORs and academic failures (E. Lashua, personal communication, January 18, 2011).

7. Stage 5: C-Pool

There are five primary training squadrons, three at NAS Whiting Field, FL and two at NAS Corpus Christi, TX. This requires 40% of the students to transfer and conduct a permanent change of station (PCS) move to NAS Corpus Christi. The remaining 60% of the students stay in the Pensacola area and transfer to NAS Whiting Field, which does not require a PCS move.

PCS moves are inherently costly to the aviation-training program in terms of time and money. Many variables go into the calculation of PCS costs. Students are allowed up to 10,000 pounds of HHG with an average being 5,000 lbs. Distance is also a factor with the distance between NAS Pensacola and NAS Corpus Christi approximately 760 miles with associated cost per mile. Distance is also a major factor determining the number of days spent on the road while calculating per diem rates to cover food and lodging while traveling. For example, the distance of 760 miles between NAS Pensacola and NAS Corpus Christi is divided by the standard traveling distance per day to arrive at 2.17, which is rounded to two days. This number is then multiplied by the per diem rate per day. Once arriving at the new duty station of NAS Corpus Christi, students are eligible to receive 10 days of house hunting leave to find and set up their house prior to checking-into their primary squadron. During this time, the students receive Temporary Lodging Expense (TLE) of $180 per day for a maximum of 10 days of house hunting leave. These costs are depicted in Table 9 of Appendix A resulting in a total cost to transfer a student of $10,040. This cost, spread across all students in the program results in an overall cost per student within the training program of $4,020.

Table 2. Transfer Costs: NAS Pensacola to NAS Corpus Christi (From Chief of Naval Air Training (CNATRA) Instruction 3501.1B Introductory Flight Screening (IFS) Program; Navy Times Pay charts at http://www.navytimes.com/money/pay_charts/, December 2010.

Transfer Costs NAS Pensacola -> NAS Corpus Christi)	Unit Cost	Units	Total
- HHG Weight (lbs.)	$1	5,000	$5,000
- Distance Traveled (miles)	$.25	760	$190
- Per Diem (days)	$140	2	$280
- Temporary Lodging Expense (days)	$180	10	$1,800
- House Hunting Leave (days)	$90	10	$900
Dislocation Allowance	$1,320	1	$1,320
Fly Pay*	$0	10	$0
Retired Pay Accrual	$30	10	$300
Medicare-Eligible Retiree Health Care Accrual	$25	10	$250
Total Average Transfer Cost per Student			$10,040

*Note: SNA fly pay starts during primary stage of training

Once PCS transfer is complete and students check into a primary squadron, holding costs apply as students await the start of the next stage of training. Differences in Basic Allowance for Housing (BAH) rates between students at NAS Whiting Field and NAS Corpus Christi are accounted. The composite cost to hold students in C-Pool is calculated in Table 10 of Appendix A. This results in an average biweekly cost of $2,685.

8. Stage 6: Primary Flight Training

Primary pilot training is flown in the T-34C and is divided into four phases. Phases are grouped by like flight training events, such as contact, instrument, navigation and formation. The average time to train is 127 training days for students assigned to squadrons at NAS Corpus Christi and 131 training days for students assigned to NAS Whiting Field (CNATRA, 2009, p. vii). Flights are primarily scheduled five days a week, Monday through Friday. Therefore, the expected total time to complete the program is 177 calendar days for students assigned to NAS Corpus Christi and 183

calendar days for students assigned to NAS Whiting Field (i.e., 13 time periods). Composite personnel holding costs associated with this time to train are depicted in Table 10 Appendix A and are calculated resulting in a biweekly cost of $2,740.

Variable training costs based on cost per flight hour also must be taken into consideration. Flight hours are based on actual syllabus flight time allotted. Instructional time may vary +/- .3 hours per flight without explanation. Therefore, total time to train may range from 75.9 hours to 102.2 hours (CNATRA, 2009, p. x). Calculations in this paper will utilize average time to train of 89.0 hours as assigned in the flight syllabus. An overview of the flight syllabus is depicted in Table 12 in Appendix B. Students undergoing primary pilot training fly in the T-34C "Mentor" aircraft with FY2010 cost per flight hour determined to be $348 (E. Lashua, personal communication, January 18, 2011). This results in a training cost per student of $30,972 based on the syllabus flight hours. Cockpit Procedures Trainer (CPT) and Simulators (SIM) are synthetic trainers of the cockpit environment and are considered sunk costs.

Attritions from this phase of the program are historically 8.0% and are assumed to occur at the end of the program (E. Lashua, personal communication, January 18, 2011). At the completion of the primary flight program, students are assigned one of the five platforms—jet, E-6, maritime, tilt-rotor or rotary types of aircraft—that they will fly throughout their naval career.

9. Stage 7: D-Pool

D-Pool is similar to C-Pool containing both transfer costs and holding costs. Transfer costs of students moving from squadrons located at NAS Corpus Christi, TX to NAS Whiting Field, FL is $10,690 per student transferred or $4,275 spread among all students.

Table 3. Transfer Costs: NAS Corpus Christi to NAS Whiting Field (From Chief of Naval Air Training (CNATRA) Instruction 3501.1B Introductory Flight Screening (IFS) Program; Navy Times Pay charts at http://www.navytimes.com/money/pay_charts/, December 2010.

Transfer Costs (NAS Corpus Christi -> NAS Whiting Field)	**Unit Cost**	**Units**	**Total**
- HHG Weight (lbs.)	$1	5,000	$5,000
- Distance Traveled (miles)	$0	780	$780
- Per Diem (days)	$150	2	$300
- Temporary Lodging Expense (days)	$180	10	$1,800
- House Hunting Leave (days)	$90	10	$900
Dislocation Allowance	$1,320	1	$1,320
Fly Pay	$4	10	$40
Retired Pay Accrual	$30	10	$300
Medicare-Eligible Retiree Health Care Accrual	$25	10	$250
Total Average Transfer Cost per Student			$10,690

The composite cost to hold students in D-Pool is calculated in Table 10 of Appendix A. This results in an average biweekly cost of $2,660.

10. Stage 8: Advanced Rotary Flight Training

Advanced helicopter pilot training is flown in two models of the TH-57 training helicopter, the basic model (TH-57B) and the instrument rated model (TH-57C). This stage is divided into five phases, contact, instrument, navigation and formation, and tactical. Overall time to train is 133 training days or 205 calendar days (i.e., 15 time periods) (CNATRA, 2009, p. vii). Flights are primarily scheduled five days a week, Monday through Friday, although flights may be scheduled on Sunday for recovering cross country flights. Composite personnel holding costs associated with this time to train (TTT) are depicted in Table 10 in Appendix B. This results in an average biweekly cost of $2,660.

Cost per flight hour also must be taken into consideration. Average cost per flight hour for the TH-57 is calculated at $525. Flight hours are based on actual syllabus scheduled time allotted. Instructional time may vary +/- 0.3 hours per flight. Therefore,

total time to train will range from 102.7 hours to 123.1 hours (CNATRA, 2009, p. ix). Deviation in excess of this range must be documented with reasons why. Calculations in this paper will utilize average time to train of 112.9 hours as assigned in the primary flight syllabus. This syllabus is described in Table 15 in Appendix B. This results in the training cost per student of $59,273 based on the syllabus flight hours. CPT and SIM are synthetic trainers of the cockpit environment. Costs associated with these events are set under contract with Raytheon and are considered sunk costs. Attritions from this phase of the program are on average 7.4% based on historical data and are assumed to occur at the end of the program (E. Lashua, personal communication, January 18, 2011). At the completion of the Advanced Helicopter Flight Training stage, students enter E-Pool awaiting their winging ceremony.

11. Stage 9: E-Pool

The winging ceremony is the graduation from the aviation helicopter pilot training. This pool is included in the supply-chain model because queues are built up waiting for the ceremony to occur. Winging ceremonies take place every two weeks with minimum time waiting in the queue of 0 days for students just finishing their last flight the day prior to those that just missed the cut off from the prior ceremony and must wait the entire 14 days. Average time spent in the queue, therefore, is calculated at seven days. Composite personnel costs for time spent in this queue are shown in Table 11 in Appendix A. This results in an average biweekly cost of $2,660.

12. Stages 10/11: F-Pool / Fleet Replacement Squadrons (FRS)

Upon completion of the undergraduate flight training, the newly designated naval pilots enter another pool to await the start of the FRS. In the FRS, the newly winged naval pilots undergo further customization training in the particular type/model of aircraft they will fly in the fleet before final delivery to the fleet squadrons that had originally ordered the student. At the fleet squadron, the supply-chain management continues with

the ordering of future placements as discussed in previous sections. These activities occurring after completion of the undergraduate training program fall outside the scope of this study and are not discussed in detail.

C. COMPOSITE COSTS

These calculated costs for each stage, transfer costs (CXTRs), holding costs (CHLDs) and training costs (CTRNs) are holding costs for each stage (CHLDs)are depicted in Figure 2 and are used in Chapter III building the model.

Table 4. Helicopter Training Program Variable Costs per Time Period

Stage	Time Period	Transfer ($CXFR_s$)	Hold ($CHLD_s$)	Train ($CTRN_s$)
1. A-Pool	N/A	$0	$2,605	$0
2. Introductory Flight Screening (IFS)	4	$0	$2,605	$3,760
3. B-Pool	N/A	$0	$2,605	$0
4. Aviation Preflight Indoctrination (API)	4	$0	$2,605	$0
5. C-Pool	N/A	$4,020	$2,685	$0
6. Primary Flight Training	13	$0	$2740	$30,972
7. D-Pool	N/A	$4,275	$2,660	$0
8. Advanced Rotary Flight Training	15	$0	$2,660	$59,273
9. E-Pool	N/A	$0	$2,660	$0

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III. OPTIMIZATION MODEL

Utilizing the transfer, training and holding composite costs calculated in Chapter II and introducing a penalty cost for over and under production, a simple linear programming model is formulated to determine the SNA training rate, as well as SNA loads and wait times in the various stages of the undergraduate training program. SNAs are tracked throughout the program in specific time buckets or periods. These periods are determined to be equivalent to fourteen days based on the scheduling of biweekly graduation of newly winged pilots. Notation for the variables used throughout the formal model is explained in Table 5.

Table 5. Notation for Helicopter Pilot Training Manpower System

$API_p(t)$	Number of SNAs progressing through API during time segment *p* in time period *t* for p = {1, 2, 3, 4, 5}; t = {1, 2, …, 52}
$ADV_p(t)$	Number of SNAs progressing through Advanced Rotary Flight Training during time segment *p* in time period *t* for p = {1, 2, 3, 4, 5}; t = {1, 2, …, 52}
$\beta_s(t)$	Number of SNAs in stage *s* at time period *t* that are solved to advance to the next stage in the next time period for each s = {0, 2, 4, 6, 8}; t = {0, 1, …, 52} $\beta_s(t)$ for s = {1, 3, 5, 7, 9}, while not decision variables, are intermediate
	variables used to track students through the system.
$CHLD_s$	Cost to hold SNAs during stage *s* for each s = {1, 2, …, 9}
$CTRN_s$	Cost to train SNAs during stage *s* for each s = {1, 2, …, 9}
$CXFR_s$	Cost to transfer SNAs during stage *s* for each s = {1, 2, …, 9}
$D_y^+(t)$	Overproduction of SNAs during year *y* and time period *t* for y = {1, 2}; t = {0, 1, …, 52}
$D_y^-(t)$	Underproduction of SNAs during year *y* and time period *t* for y = {1, 2}; t = {0, 1, …, 52}

$\alpha_s(t)$	Number of SNAs in stage *s* at time period *t* that enter into stage s at time period t for each s = {0, 2, 4, 6, 8}; t = {0, 1, …, 52}.
δ_s	Average attrition rate for all SNAs at the completion of stage *s* for each s = {1, 2, …, 9}
$IFS_p(t)$	Number of SNAs progressing through IFS during segment *p* in time period *t* for p = {1, 2, 3, 4, 5}; t = {1, 2, …, 52}
MAX_s	Maximum number of SNAs able to be produced during stage *s* due to capacity for each s = {1, 2, …, 9}
MIN_s	Minimum number of SNAs required to be produced during stage *s* to maintain flow of supply chain for each s = {1, 2, …, 9}
$PRI_p($ $PRI_p(t)$	Number of SNAs progressing through Primary Flight Training during segment *p* in time period *t* for p = {1, 2, 3, 4, 5}; t = {1, 2, …, 52}
$P_s(t)$	The observed number of SNAs during stage *s* in time period *t* for each s = {0, 1, …, 12}; t = {0, 1, …, 52}
PEN	Penalty cost for over and under production taken at the end of each FY.

A. INPUTS

The required number of pilots within fleet squadrons is constrained regardless of conditions of peacetime, contingencies or wartime, by required minimum training levels, as well as number of aircraft and ship platform types from which to deploy. Military planners receive demands for fill vacancies of qualified pilots departing the fleet squadrons and progress along the aviation career track. Production requirements for the undergraduate training program varies only slightly between biweekly time periods utilized by the mode and is approximately spread evenly throughout the year in an attempt to retain corporate knowledge within the different communities. Historically variations of the fleet demands can be determined utilizing Navy budgetary data, as depicted in Figure 7.

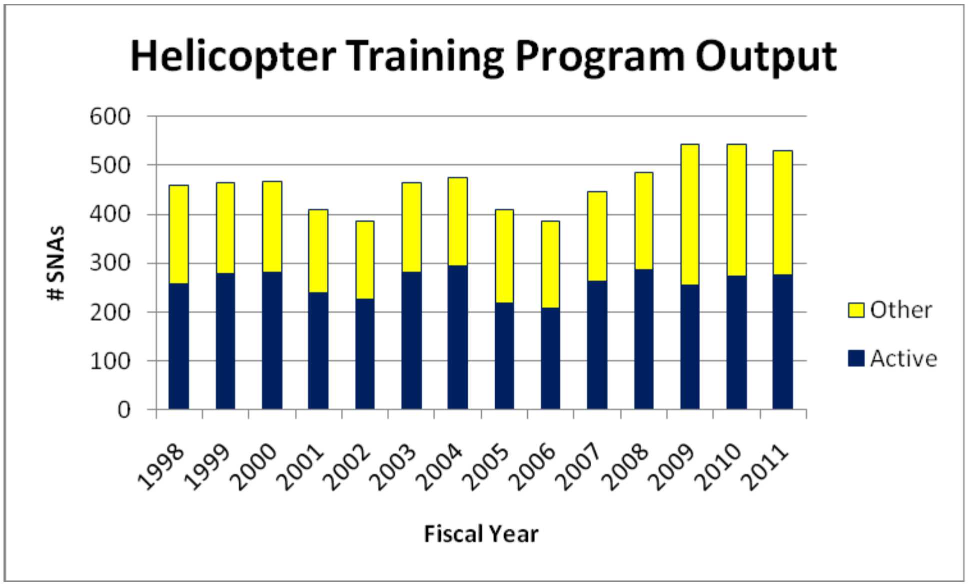

Figure 7. Helicopter Training Program Outputs (From Department of Navy Operation & Maintenance (O&M) Budgetary Data FY1998 through FY2010)

Taking the standard deviation of the past decade results in a standard deviation of approximately 2.0 for each of biweekly time periods. However, this is considered high given the changes both in naval operational tempo (OPTEMPO) and within the aviation community in the past decade. A more accurate standard deviation is calculated using a weighted moving average with recent years weighted higher than more distant years. A calculated number results in a value of approximately 0.50 for each of the biweekly time periods and is the value utilized for the model.

Using Microsoft Excel's function of Random Number Generator, variability in the number of required pilots can be introduced into the model. Excel's Random Number Generator function can be found under Data Analysis and Random Number Generation, as depicted in Figure 8 and Figure 9. Given a normal distribution, mean, and standard deviation, numbers are generated for 115 inputs representing 15 periods prior to the start of the model, 52 periods of the model, and 100 periods after the model ends. The pre and posttime periods are a necessary part of the model to determine predefined starting inventory and rates, as well as postdefined rates upon which the model calls.

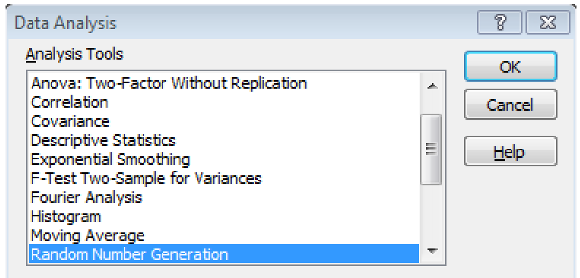

Figure 8. Data Analysis Tools

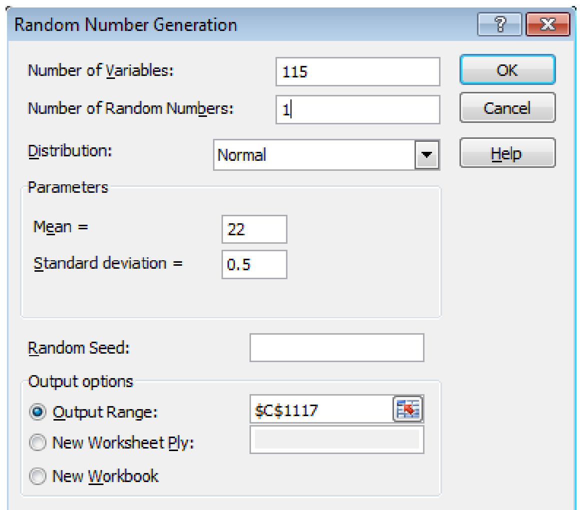

Figure 9. Random Number Generation

B. MODEL

The model worksheet contains user-defined inputs based on historical data affecting each stage to include minimum demands to ensure proper flow within the training program, attrition rates for the various training stages, and constraints. The linear programming model consists of 52 biweekly periods covering a 2-year period. In this model, there are 264 decision variables and 1,303 constraints that exceed the capabilities of Microsoft Excel Solver. Therefore, Frontline's Risk Solver Premium 10.0 is used to solve the model.

1. Decision Variables

There are three types of decision variables used in the objective function of this model, $\beta_s(t)$, $D_y^+(t)$ and $D_y^-(t\ )$. The decision of the flight program manager to remove SNAs from one of the various pools when s = {1, 3, 5, 7, 9}) at a specific time period, *t*, within the training program to meet demand of the next stage of the process is captured within the variable $\beta_s(t)$. During actual training stages when s = {0, 2, 4, 6, 8}, students are tracked through the specific stage. Completion of this training stage requires no decision with SNAs automatically entering the next pooling state.

The decision variables, $D_y^+(t)$ and $D_y^-(t)$, are included in the model to ensure linearity is maintained in adding a fourth cost into the objective function, a penalty cost. This penalty is used as an incentive to meet SNA training goals and is incurred at the end of a fiscal year, when t = {26, 52}. This penalty is not calculated on a biweekly basis, thus allowing output of the program to fluctuate with squadrons over and under producing at the end of each biweekly period without incurring a penalty.

2. Objective Function

The objective function in this model will be constructed to minimize overall costs of the helicopter pilot training program for a two-year time period. SNAs entering the program from the commissioning sources at various times are represented by $\beta_0(t)$. Once in the program, the number of SNAs leaving one stage in time period *t* for the next phase are represented by $\beta_s(t)$. Both $\beta_0(t)$, for students assigned prior to the start of the program, and $\beta_s(t)$, representing students within the different stages and time periods of the program, are calculated through the simulation of the model. Students within the program incur a cost to hold, train and transfer. These costs are explained in depth in Chapter II and are summarized in Table 4. Given these costs, the objective function can be written as follows.

Minimize Overall Variable Costs =

$$\min \left[\sum_{s=1}^{9} \sum_{t=1}^{52} (CXFR_s + CTRN_s) * \beta_{s-1}(t-1) + CHLD_s * P_s(t) \right]\Big] + \sum_{y=1}^{2} PEN * (D_y^{+} + D_y^{-})$$

This can be expanded to be written as:

Minimize Overall Variable Costs =

$$\min \Big[\underbrace{\$1{,}303 * \sum_{t=1}^{52} P_1(t)}_{\text{A-Pool IFS}} + \underbrace{\$3{,}760 * \sum_{t=1}^{52} \beta_1(t-1) + \$1303 * \sum_{t=1}^{52} P_2(t)}$$

$$+ \underbrace{\$1{,}303 * \sum_{t=1}^{52} P_3(t)}_{\text{B-Pool API}} + \underbrace{\$1{,}303 * \sum_{t=1}^{52} P_4(t)}$$

$$+ \underbrace{\$4{,}020 * \sum_{t=1}^{52} \beta_4(t-1) + \$1{,}346 * \sum_{t=1}^{52} P_5(t)}_{\text{C-Pool}} + \underbrace{\$30{,}972 * \sum_{t=1}^{52} \beta_5(t-1) + \$1{,}370 * \sum_{t=1}^{52} P_6(t)}_{\text{Primary Flight Training}}$$

$$+ \underbrace{\$4{,}275 * \sum_{t=1}^{52} \beta_6(t-1) + \$1{,}330 * \sum_{t=1}^{52} P_7(t)}_{\text{D-Pool}} + \underbrace{\$59{,}273 * \sum_{t=1}^{52} \beta_7(t-1) + \$1{,}330 * \sum_{t=1}^{52} P_8(t)}_{\text{Advanced Rotary Flight Training}}$$

$$+ \underbrace{\$1,330 * \sum_{t=1}^{52} P_9(t)}_{\text{E-Pool}} + \underbrace{\sum_{y=1}^{2} (50,000 * D_y^{+} + \$50,000 * D_y^{-})]}_{\text{Over/Under Production Penalty}}$$

3. Constraints

a. Predefined Starting and Ending Rates and Inventories

Given the demands for qualified pilots, the number of SNAs entering the program starting each of the training stages can be determined. Attrition rates, based on historical data, are taken into account to ensure adequate number of students begin the training program at the right time period. This number of students is calculated by the model and can be described entering the program, as described in Table 6.

Table 6. SNA Calculated Demand by Stage

Stage	s	Attrition	Input Rate	Output Rate
Fleet Squadron	12	$\delta 12$	$\alpha_{12} = \beta_{12} / (1-\delta_{12})$	β_{12}
FRS	11	$\delta 11$	$\alpha_{11} = \beta_{11} / (1-\delta_{11})$	$\beta_{11} = \alpha_{12}$
F-Pool	10	$\delta 10$	$\alpha_{10} = \beta_{10} / (1-\delta_{10})$	$\beta_{10} = \alpha_{11}$
E-Pool	9	$\delta 9$	$\alpha_9 = \beta_9 / (1-\delta_{19})$	$\beta_9 = \alpha_{10}$
Advanced Rotary Flight Training	8	$\delta 8$	$\alpha_8 = \beta_8 / (1-\delta_8)$	$\beta_8 = \alpha_9$
D-Pool	7	$\delta 7$	$\alpha_7 = \beta_7 / (1-\delta_7)$	$\beta_7 = \alpha_8$
Primary Flight Training	6	$\delta 6$	$\alpha_6 = \beta_6 / (1-\delta_6)$	$\beta_6 = \alpha_7$
C-Pool	5	$\delta 5$	$\alpha_5 = \beta_5 / (1-\delta_5)$	$\beta_5 = \alpha_6$
API	4	$\delta 4$	$\alpha_4 = \beta_4 / (1-\delta_4)$	$\beta_4 = \alpha_5$
B-Pool	3	$\delta 3$	$\alpha_3 = \beta_3 / (1-\delta_3)$	$\beta_3 = \alpha_4$
IFS	2	$\delta 2$	$\alpha_2 = \beta_2 / (1-\delta_2)$	$\beta_2 = \alpha_3$
A-Pool	1	$\delta 1$	$\alpha_1 = \beta_1 / (1-\delta_1)$	$\beta_1 = \alpha_2$
Commissioning Source	0	---	$\alpha_0 = \beta_0 / (1-\delta_0)$	$\beta_0 = \alpha_1$

Table 6 is also utilized to approximate a predefined initial rate and inventory levels of SNAs within the program prior to the start of the model during time periods t = {-14, -13, …, 0}, as well as postending rates after model completion during time periods t = {53, 54, …, 100}

b. Commissioning Sources

Calculation of the number of SNAs required to enter the program can be determined utilizing Table 3. However, this is complicated with the arrival of students around two main periods during the year. The commissioning sources provide SNAs to the undergraduate training program in two batches after graduation following the spring and fall periods. The constraint-limiting students to arrive in these two batches can be written as:

$$\beta_0(t) = 0 \text{ for } t \neq \{6, 19, 32, 45\}.$$

c. A-Pool

Within A-Pool, SNA loading during a specific time period must follow standard supply chain rules with inputs equal to outputs (i.e., students cannot be created nor destroyed, they can only be progressed, retained, or attrited). This supply-chain for A-Pool can be written as:

$$P_1(t) = P_1(t\text{-}1) + \beta_0(t) - \beta_1(t) \quad \text{for } t = \{1, 2, \ldots, 52\}.$$

Fluctuations of the number of SNAs held within A-Pool are allowed and are expected as a result of the batching of SNAs entering the program, therefore, no restriction are imposed on the baseline model as to the minimum or maximum levels of SNAs held as safety stock.

d. Introductory Flight Screening (IFS)

The IFS training stage is conducted over a time period of 50 days, which equates to approximately four time periods. SNAs are tracked through this stage until completion. Therefore, with inputs equal to outputs, the number of students exiting the program either by completion or attrition equals the number of students entering the IFS stage from A-Pool four periods prior. This can be written as:

$$\beta_2(t) = \beta_1(t-3) * (1-\delta_2) \text{ for } t = \{1, 2, \ldots, 52\}.$$

Likewise, the SNA load, or number of SNAs, within the IFS stage is the summation of the number of students within the four time periods. This can be written as:

$$P_2(t) = \beta_1(t) + \beta_1(t-1) + \beta_1(t-2) + \beta_1(t-3) \text{ for } t = \{1, 2, \ldots, 52\}.$$

Minimum SNA demand is a required constraint for each of the training stages to ensure proper flow through the entirety of the supply chain. Without this constraint, student flow continues until fleet demand is achieved for the 52 biweekly periods; however, once achieved, all training stops throughout the entire undergraduate helicopter training program supply chain. This, while optimal for the time period t =1, 2, …, 52}, is not optimal for future periods. Therefore, a constraint must also be written to ensure minimum flow within the supply chain is maintained. This constraint can be written as:

$$\alpha_2(t) \geq MIN_2 = [\ \Sigma\ \beta_1(t) / 52\ ] \text{ for } t = \{1, 2, \ldots, 52\}.$$

Capacity is another constraint of the each of the training stages. There are five civilian flight schools supporting IFS training located in the Pensacola area, two in Pensacola, one Milton, one in Gulf Shores, and one in Mobile (CNATRA, 2010). Among these five schools, there are approximately 40 flight instructors (K. Coleman, personal communication, January 7, 2011). In accordance with Federal Aviation Regulations, civilian flight instructors are limited to a maximum of eight hours of instructional flights per 24-hour period, which equates to approximately four flights per day for the Jeppesen civilian flight syllabus (FAA, 2011). There are 23 instructional and two noninstructional (i.e., solo) flights contained in the IFS syllabus (CNATRA, 2007, p. 9). The IFS constraint is the total students produced biweekly. During the IFS stage, future helicopter students make up 35.9% of the total number of IFS flight students

(Assistant Secretary of the Navy, 2001–2010). IFS start dates are on an as required basis, dependent on individual SNAs schedules. Therefore, the capacity constraint can be written as:

$$\beta_2(t) \leq MAX_2 \text{ for } t = \{1, 2, \ldots, 52\}$$

with MAX_2 calculated as:

$$MAX_2 = (40 \text{ CFIs} * (4 \text{ instructional flights} / 23 \text{ student flights}) * 14 \text{ days}) \\ * .359 \text{ future helicopter students per total IFS students}$$

$$MAX_2 = 34.96 \text{ future helicopter students completed weekly.}$$

e. B-Pool

Within B-Pool, SNA loading during a specific time period must follow standard supply chain rules with inputs equal to outputs. This supply-chain for B-Pool can be written as:

$$P_3(t) = P_3(t\text{-}1) + \beta_2(t) - \beta_3(t) \text{ for } t = \{1, 2, \ldots, 52\}.$$

As with A-Pool, some fluctuations of the number of SNAs held within B-Pool are allowed and are expected as a result of batching of SNAs entering the program. Therefore, no restrictions are imposed as to the minimum or maximum levels of SNAs held as safety stock in the baseline model.

f. Aviation Preflight Indoctrination (API)

The API training stage is conducted over a time period of seven weeks, which is approximately four time periods. SNAs are tracked through this stage until completion. Therefore, with inputs equal to outputs, the number of students exiting the program either by completion or attrition equals the number of students entering the API stage from B-Pool four periods prior. This can be written as:

$$\beta_4(t) = \beta_3(t-3) * (1-\delta_4) \text{ for } t = \{1, 2, \ldots, 52\}.$$

Likewise, the SNA load, or number of SNAs, within the API stage is the summation of the number of students within the four time periods. This can be written as:

$$P_4(t) = \beta_3(t) + \beta_3(t-1) + \beta_3(t-2) + \beta_3(t-3) \text{ for } t = \{1, 2, \ldots, 52\}.$$

As with IFS training, minimum SNA demand is a required constraint for each of the training stages to ensure proper flow through the entirety of the supply chain. This constraint can be written as:

$$\alpha_4(t) \geq MIN_4 = [\ \Sigma\ \beta_3(t) / 52\ ] \text{ for } t = \{1, 2, \ldots, 52\}.$$

Pure ground instructional stages, such as API, are limited by classroom size. Maximum class size for this stage is limited to 50 students (E. Lashua, personal communication, January 18, 2011). Of the total number of students, the number of future helicopter students makes up 35.9% of the total (Assistant Secretary of the Navy, 2001–2010). API start dates are on a weekly schedule (Bostick & Booth, 2005, p. 20). Therefore, the capacity constraint can be written as:

$$B_4(t) \leq MAX_4 \text{ for each } t = \{1, 2, \ldots, 52\}$$

with MAX_4 calculated as:

MAX_4 = (50 API students per class) * .359 future helicopter pilots per total students * 2 classes per two-week time period

MAX_4 = 35.9 future helicopter pilots completed biweekly.

g. C-Pool

Within C-Pool, SNA loading during a specific time period must follow standard supply chain rules with inputs equal to outputs. This supply-chain for C-Pool can be written as:

$$P_5(t) = P_5(t-1) + \beta_4(t) - \beta_5(t) \text{ for } t = \{1, 2, \ldots, 52\}.$$

Unlike the previous two pools, in C-Pool, an additional constraint must be introduced to ensure adequate numbers of SNAs are maintained within the pool as safety stock to protect the system from rapid and unplanned surges in demands. The more variability within the system, the more safety stock is required to be held. For C-Pool, with two groupings of SNAs unselected in platform type training at different locations, variability within this pool is greater than in D-Pool or E-Pool. Based on current data, the size of C-Pool was approximated and can be written as:

$$P_5(t) \geq 3*MIN_5 = 3 * [\ \Sigma\ \alpha_5(t) / 52\ ] \text{ for } t = \{1, 2, \ldots, 52\}.$$

h. Primary Flight Training

The Primary Flight Training stage is conducted over a time period of 180 days, which equates to approximately 13 time periods. SNAs are tracked through this stage until completion. Therefore, with inputs equal to outputs, the number of students exiting the program either by completion or attrition equals the number of students entering the Primary Flight stage from C-Pool 13 periods prior. This can be written as:

$$\beta_6(t) = \beta_5(t-12) * (1- \delta_6).$$

Likewise, the SNA load, or number of SNAs, within the Primary Flight stage is the summation of the number of students within the 13 time periods. This can be written as:

$$P_6(t) = \beta_5(t) + \beta_5(t-1) + \beta_5(t-2) + \beta_5(t-3) + \beta_5(t-4) + \beta_5(t-5) + \beta_5(t-6) + \beta_5(t-7) + \beta_5(t-8) + \beta_5(t-9) + \beta_5(t-10) + \beta_5(t-11) + \beta_5(t-12)$$
for $t = \{1, 2, \ldots, 52\}$.

As with other training stages, minimum SNA demand is a required constraint for each of the training stages to ensure proper flow through the entirety of the supply chain. This constraint can be written as:

$$\alpha_6(t) \geq MIN_6 = [\ \Sigma\ \beta_5(t) / 52\ ] \text{ for } t = \{1, 2, \ldots, 52\}.$$

There are five primary training squadrons, three at NAS Whiting Field, FL and two at NAS Corpus Christi, TX (CNATRA, 2010). Among these five squadrons, there are approximately 56 active duty flight instructors per squadron. Pilot training rate during the primary stage is determined through the number of resources available (i.e., squadrons and instructors). Maximum instructor flight time is governed through the OPNAV instruction 3710.7U (p. 8–17) and the each training wing instruction, such as COMTRAWINGFIVE Instruction 3710.2T (p. 1–3), depicted in Table 7.

Table 7. Primary Flight Training Flight Hour Limitations (From OPNAVINST 3710.7U, COMTRAWINGFIVEINST 3710.2T)

	Time Period				
Governing Instruction	**Daily**	**Weekly**	**Monthly**	**Quarterly**	**Yearly**
OPNAV 3710.7	6.5 hours	30 hours	65 hours	165 hours	595 hours
COMTRAWINGFIVEINST 3710.2T	12 hours	50 hours	100 hours	265 hours	960 hours

Flight hour waivers may be granted on a case-by-case basis to exceed OPNAV 3710.7U limits for single-piloted (i.e., instructor-student) aircraft in accordance to the Fixed-Wing SOP (p. 23), but are on a case-by-case basis to meet operational requirements. These waivers are highly dependent on flight instructor personal goals, which limit maximum flight hours flown to 595 without waivers up to 960 hours with waivers. Percentages of instructors on waivers that are used for this model are estimated to be approximately 25% of total number of instructors. Included in the flight hours are

both syllabus (i.e., instructor-student flights) and nonsyllabus (i.e., maintenance and instructor-instructor) flights. A ratio of 6.5 syllabus hours to eight total hours are estimated (81.3%) of flights are considered syllabus supporting flight hours. This results in a maximum of 483 syllabus flight hours per year per instructor. There are 80.6 instructional and 8.4 noninstructional (i.e., solo) flights contained in the primary flight syllabus (CNATRA, 2009, p. x). During this stage, future helicopter students make up 41.3% of the total number of total flight students (Assistant Secretary of the Navy, 2001–2010). Primary start dates are on a biweekly schedule (Bostick & Booth, 2005, p. 20). Therefore, the capacity constraint can be written as:

$$B_6(t) \leq MAX_6 \text{ for each } t = \{1, 2, \ldots, 52\}.$$

with MAX_6 calculated as:

MAX_6 = [.75*(280 active duty instructors) * (483 flight hours per year) + .25* (280 active duty instructors) * (780 flight hours per year)] / 80.6 student instructional hours) / 26 periods per year] * .413 helicopter students per total primary students

MAX_6 = 30.75 future helicopter students completed biweekly.

However, as mentioned previously, the maximum capacity of students in this stage is calculated assuming only 25% of the flight instructors are on waivers. In times of high OPTEMPO, this may be as high as 43.04 future helicopter pilots completed on a biweekly basis if all flight instructors are granted flight hour waivers to exceed OPNAVINST 3710.7U limitations.

i. *D-Pool*

Within D-Pool, SNA loading during a specific time period must follow standard supply chain rules with inputs equal to outputs. This supply-chain for D-Pool can be written as:

$$P_7(t) = P_7(t\text{-}1) + \beta_6(t) - \beta_7(t) \quad \text{for } t = \{1, 2, \ldots, 52\}.$$

As with C-Pool, an additional constraint must be introduced to ensure adequate numbers of SNAs are maintained within the pool as safety stock that protects the system from rapid and unplanned surges in demands. For D-Pool, with SNAs entering the pool from two different locations, there is less variability than in C-Pool but more variation than E-Pool. Based on current data, the size of D-Pool is approximated and written as:

$$P_7(t) \geq 2{*}MIN_7 = 2 * [\, \Sigma\, \alpha_7(t) / 52 \,] \text{ for } t = \{1, 2, \ldots, 52\}.$$

j. Advanced Rotary Flight Training

The Advanced Rotary Flight Training stage is conducted over a time period of 205 days, approximately 15 time periods. SNAs are tracked through this stage until completion. Therefore, with inputs equal to outputs, the number of students exiting the program either by completion or attrition equals the number of students entering the Primary Flight stage from C-Pool 15 periods prior. This can be written as:

$$\beta_8(t) = \beta_7(t\text{-}14) * (1\text{-} \delta_8).$$

Likewise, the SNA load, or number of SNAs, within the Advanced Rotary Flight stage is the summation of the number of students within the 15 time periods. This can be written as:

$$\begin{aligned} P8(t) = {} & \beta7(t) + \beta7(t\text{-}1) + \beta7(t\text{-}2) + \beta7(t\text{-}3) + \beta7(t\text{-}4) + \beta7(t\text{-}5) + \beta7(t\text{-}6) \\ & + \beta7(t\text{-}7) + \beta7(t\text{-}8) + \beta7(t\text{-}9) + \beta7(t\text{-}10) + \beta7(t\text{-}11) + \beta7(t\text{-}12) \\ & + \beta7(t\text{-}13) + \beta7(t\text{-}14). \end{aligned}$$

As with other training stages, minimum SNA demand is a required constraint for each of the training stages to ensure proper flow through the entirety of the supply chain. This constraint can be written as:

$$\alpha_8(t) \geq MIN_8 = [\ \Sigma\ \beta_7(t) / 52\ ] \text{ for } t = \{1, 2, \ldots, 52\}.$$

Within the Advanced Rotary Flight Training, maximum capacity of the stage is determined through the number of resources available (i.e., squadrons and instructors). There are three advanced rotary training squadrons at NAS Whiting Field, FL (CNATRA, 2010). Among these three squadrons, there are approximately 56 active duty flight instructors per squadron normally flying on a daily basis and 10 reserve flight instructors per squadron flying as required to maintain minimum reserve time requirements (A. Petrosino, personal communication, January 7, 2011). As with primary flight training, the maximum instructor flight time during this phase is limited by OPNAV Instruction 3710.7U (p. 8–17) and the Training Wing Five Instruction 3710.8Q (p. 1–3), as depicted in Table 8.

Table 8. Advanced Rotary Flight Training Flight Hour Limitations (From OPNAVINST 3710.7U, COMTRAWINGFIVEINST 3710.2T

	Time Period				
Governing Instruction	**Daily**	**Weekly**	**Monthly**	**Quarterly**	**Yearly**
OPNAV 3710.7	6.5 hours	30 hours	65 hours	165 hours	595 hours
COMTRAWINGFIVEINST 3710.8Q	8 hours	50 hours	100 hours	265 hours	960 hours

As with Primary Flight Training, flight hour waivers may be granted on a case-by-case basis to exceed OPNAV 3710.7U limits for single-piloted (i.e., instructor-student) aircraft in accordance to the Fixed-Wing SOP (p. 23), but are on a case-by-case basis to meet operational requirements. These waivers are highly dependent on flight instructor personal goals, which limit maximum flight hours flown to 595 without waivers up to 960 hours with waivers. Percentages of instructors on waivers that are used

for this model are estimated to be approximately 25% of total number of instructors. Included in the flight hours are both syllabus (i.e., instructor-student flights) and nonsyllabus (i.e., maintenance and instructor-instructor) flights. A ratio of 6.5 syllabus hours to eight total hours are estimated (81.3%) of flights are considered syllabus supporting flight hours. This results in a maximum of 483 syllabus flight hours per year per instructor. There are 108.2 instructional and 4.7 noninstructional (i.e., solo) flights contained in the primary flight syllabus (CNATRA, 2009, p. ix). During this stage, helicopter students make up 96.6% of the total number of total rotary wing flight students (Assistant Secretary of the Navy, 2001–2010). Advanced rotary wing training start dates are on a biweekly schedule (Bostick& Booth, 2005, p. 20). Therefore, this constraint can be written as:

$$B_8(t) \leq MAX_8 \text{ for each } t = \{1, 2, \ldots, 52\}$$

with MAX_6 calculated as:

MAX_8 = [(.75*168 active duty instructors + 30 reserve instructors* 38/365 reserve time ratio) * (483 flight hours per year) + (.25* (168 active duty instructors)*(780 Flight Hours per Year)] / 108.2 student instructional hours) / 26 periods per year] * .966 helicopter students per total rotary students

MAX_8 = 32.67 helicopter students completed biweekly.

However, the capacity of the Advanced Rotary Flight stage may be as high as 45.83 helicopter pilots completed on a biweekly basis if all flight instructors are granted flight hour waivers to exceed OPNAVINST 3710.7U limitations.

k. E-Pool

Within E-Pool, SNA loading during a specific time period must follow standard supply chain rules with inputs equal to outputs. This supply-chain for E-Pool can be written as:

$$P_9(t) = P_9(t-1) + \beta_8(t) - \beta_9(t) \quad \text{for } t = \{1, 2, \ldots, 52\}.$$

As with C-Pool and D-Pool, an additional constraint must be introduced to ensure adequate numbers of SNAs are maintained within the pool as safety stock that protects the system from rapid and unplanned surges in demands. For E-Pool, with SNAs preparing to leave the undergraduate training program for follow on training in the FRS, there is less variability than in either C-Pool or D-Pool. The size of E-Pool was approximated and written as:

$$P_9(t) \geq MIN_9 = [\, \Sigma\, \alpha_9(t) / 52 \,] \text{ for } t = \{1, 2, \ldots, 52\}.$$

C. OUTPUTS

During the running of this model, 26 separate worksheets are provided in which to copy and paste data, as depicted in Figure 10.

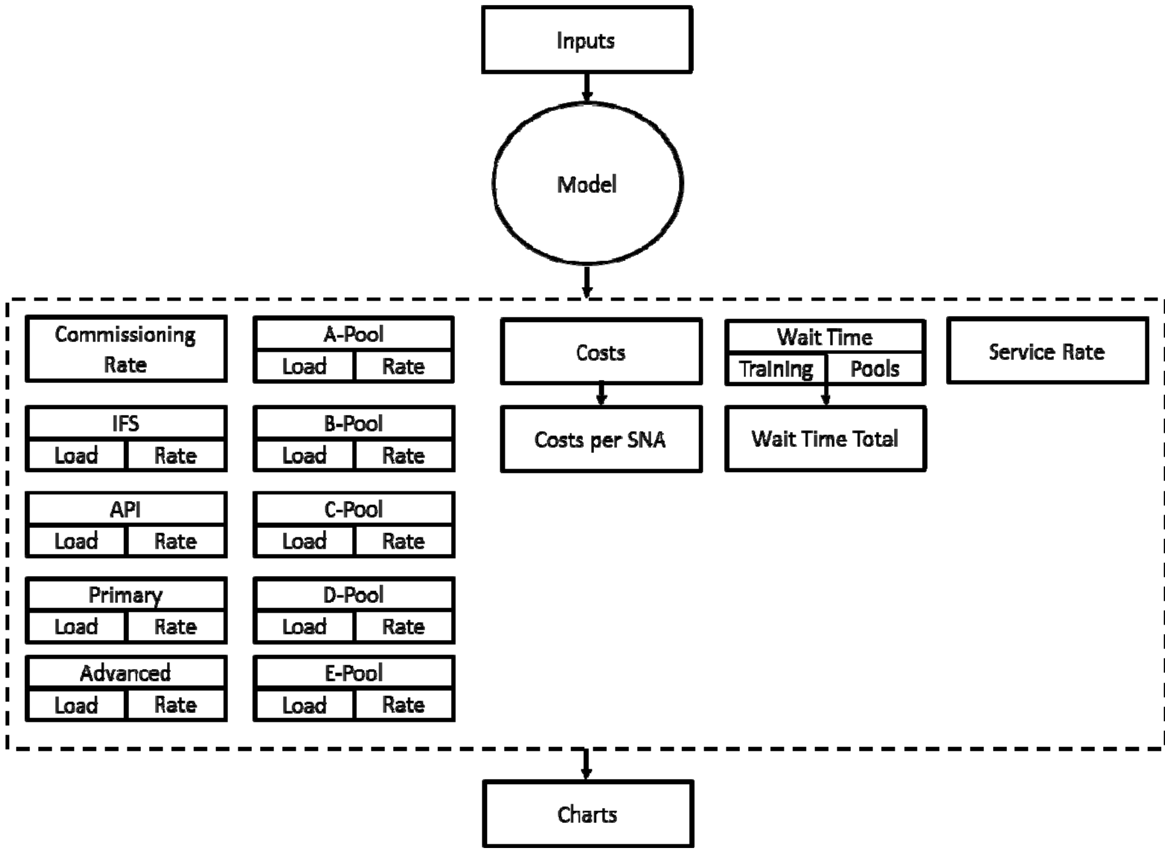

Figure 10. Worksheet Relationship Schematic

Each worksheet is named for contents that it holds. These worksheets include *Commissioning Rate*, *A-Pool Rate*, *A-Pool Load*, *IFS Rate*, *IFS Load*, *B-Pool Rate*, *B-Pool Load*, *API Rate*, *API Load*, *C-Pool Rate*, *C-Pool Load*, *Primary Rate*, *Primary Load*, *D-Pool Rate*, *D-Pool Load*, *Advanced Rate*, *Advanced Load*, *E-Pool Rate*, *E-Pool Load*, *Wait Time Training*, *Wait Time Pools*, *Wait Time Total, Costs, Costs per SNA*, and *Service Rate.* From these tables, various charts are automatically calculated and are contained in a single worksheet named *Charts.*

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IV. COMPUTATIONAL EXPERIMENT AND RESULTS

This chapter provides the information required to setup and run the computational experiment within Microsoft Excel, as well as an interpretation of the results. The initial model developed will be used as a basis to which to compare alternate models, as discussed in Chapter V.

A. SIMULATION INPUTS

The baseline model is developed to account for a simulated number of required qualified fleet pilots throughout a broad spectrum of SNAs ranging from zero up to and including the capacity of the system. Variability of the fleet demands within each scenario are taken into account, as described in Chapter III, with 50 simulation iterations for each mean number of SNAs ranging from 0 to 27. Microsoft Excel's random number generator function, shown in Figure 10, is again used multiple times to simulate fluctuations of fleet demand throughout the 52 biweekly periods (i.e., two years).

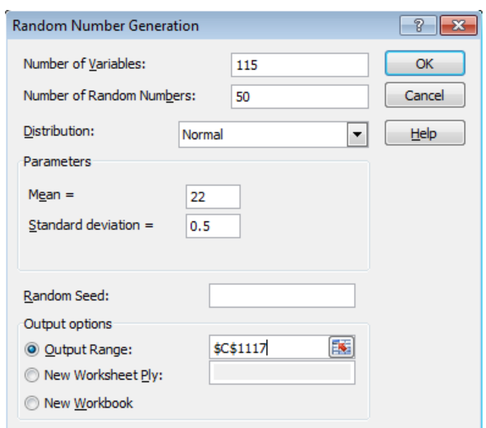

Figure 11. Fleet Demand Simulation Using Random Number Generation

Standard deviation was assumed to be 0.5, as described in Chapter III based on a mean approximately equal to 22 in accordance with historical data. Using this as the basis, the coefficient of variation (CV) was calculated by dividing standard deviation by

the mean, resulting in a CV of 0.0227. Setting this CV as a constant, the standard deviations of the other mean level of fleet demands were calculated, as depicted in Table 9.

Table 9. Fleet Demand Mean and Standard Deviation

Row #	Mean	Std Dev	CV
1 to 50	0.00	0.00	0.02
51 to 100	1.00	0.02	0.02
101 to 150	2.00	0.05	0.02
151 to 200	3.00	0.07	0.02
201 to 250	4.00	0.09	0.02
251 to 300	5.00	0.11	0.02
301 to 350	6.00	0.14	0.02
351 to 400	7.00	0.16	0.02
401 to 450	8.00	0.18	0.02
451 to 500	9.00	0.20	0.02

Row #	Mean	Std Dev	CV
501 to 550	10.00	0.23	0.02
551 to 600	11.00	0.25	0.02
601 to 650	12.00	0.27	0.02
651 to 700	13.00	0.30	0.02
701 to 750	14.00	0.32	0.02
751 to 800	15.00	0.34	0.02
801 to 850	16.00	0.36	0.02
851 to 900	17.00	0.39	0.02
901 to 950	18.00	0.41	0.02
951 to 1000	19.00	0.43	0.02

Row #	Mean	Std Dev	CV
1001 to 1050	20.00	0.45	0.02
1051 to 1100	21.00	0.48	0.02
1101 to 1150	22.00	0.50	0.02
1151 to 1200	23.00	0.52	0.02
1201 to 1250	24.00	0.55	0.02
1251 to 1300	25.00	0.57	0.02
1301 to 1350	26.00	0.59	0.02
1351 to 1400	27.00	0.61	0.02

From these actions, a 115 x 1400 table consisting of 161,000 data points with a minimum value of zero and maximum value of 27.61 and having a mean of 13.50 and standard deviation of 8.1 is created within the *Inputs* worksheet containing different simulated scenario inputs within the model ranging from zero up to and including 27.5, the capacity of the system as modeled. The resultant simulated fleet demand is depicted in Figure 12.

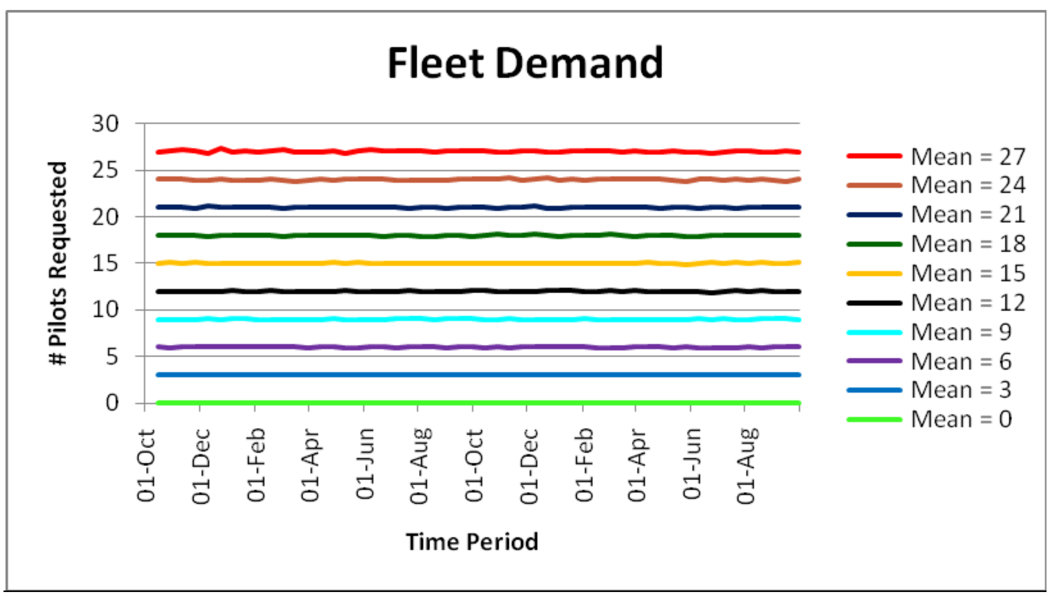

Figure 12. Fleet Demand

B. COMPUTATIONAL EXPERIMENTATION

With the creation of the model in Chapter III and the table of simulated demands, computational experimentation is next. Rather than manually set up the scenario, solve, and record the data for each of the 1,400 simulated runs, an additional tool is necessary. Macros within the Microsoft Excel program can perform these tedious operations and are accessible on the ribbon of selections under the *View* tab.

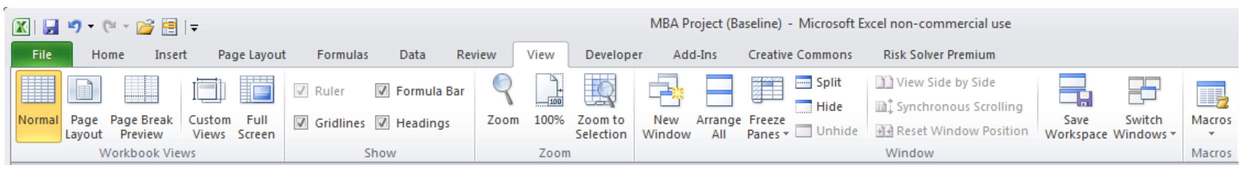

Figure 13. Accessing Microsoft Excel Macros

Within the *Model* worksheet, macros were recorded using the macros drop down menu and utilizing the *Record Macro* function. All operations for an entire simulation cycle, from copying and pasting of the simulated fleet demand, running solver and copying and pasting the results into the various output worksheets listed in Chapter III, were then executed. Steps within this macro consisted of three main phases.

- Inputs regarding simulated fleet demands were copied from the *Inputs* worksheet and pasted into the *Model* worksheet
- Risk Solver Premium v10.0 was executed
- Data was copied from numerous cells within the *Model* worksheet and pasted in the tables located in the various output worksheets

After stopping the recording of the macro, the macro was edited to ensure proper execution over multiple simulation iterations. A variable designated *Counter* was included to track simulation iteration, which was used to offset rows and columns when cutting and pasting during the execution of the macro.

Through the combination of hardware and software described in Chapter III, solving the optimization model for each scenario took approximately 15 seconds. The average uninterrupted run time for the 1400 simulations required approximately nine

hours and 30 minutes. After the full run of the simulation, various tables were automatically populated and graphs were created depicting the nine stages modeled within the undergraduate helicopter-training program.

C. RESULTS

General activities within each stage of the two-year time period are described covering the entire range of mean number of pilots demanded by the fleet squadrons from zero to 27, the capacity of the system as calculated in Chapter III. However, while it is best to plan ahead two years in advance, unexpected increases and decreases in student requirements may occur within this two-year training cycle. For example, increasing the number of pilots required from 22 to 23 at the end of the first fiscal year results in the normal batch size associated with 22 requested pilots and a first batch size of 347 students. However, the second batch within the first fiscal year then increases to 354 as the model anticipates the future increased demand. This batching stabilizes at the third and fourth batching with 363 SNAs required every six months. A similar process occurs when reduction of fleet demand reducing the number of required pilots from 23 to 22 with the number of SNAs reduced from 363 to 356 before stabilizing at 347. While the model described below is based on accurate and stable fleet pilot demands given two years in advance with no changes made during the training cycle, it can be adjusted to account for these increases and decreases of demands.

1. Commissioning Source

From the projected pilot replacement rate for the fleet squadrons and known historical attrition rates of each of the various training stages within the undergraduate training program, initial number of SNAs required to enter the program to produce the required number of pilots at the completion of the entire program are calculated. SNAs required from the commissioning source are spread over the two-year period in batches that occur approximately every six months corresponding to graduation dates of the commissioning sources. Numbers of SNAs leaving the commissioning source for the undergraduate helicopter training program range from a minimum of two students

required per six-month batch to 427 students required per six-month batch depending on varying level of fleet demand ranging from zero to 27. A composite chart depicting these various rates of SNAs entering the program built from the table contained in the *Commissioning Rate* worksheet. The resultant graph is depicted in Figure 14.

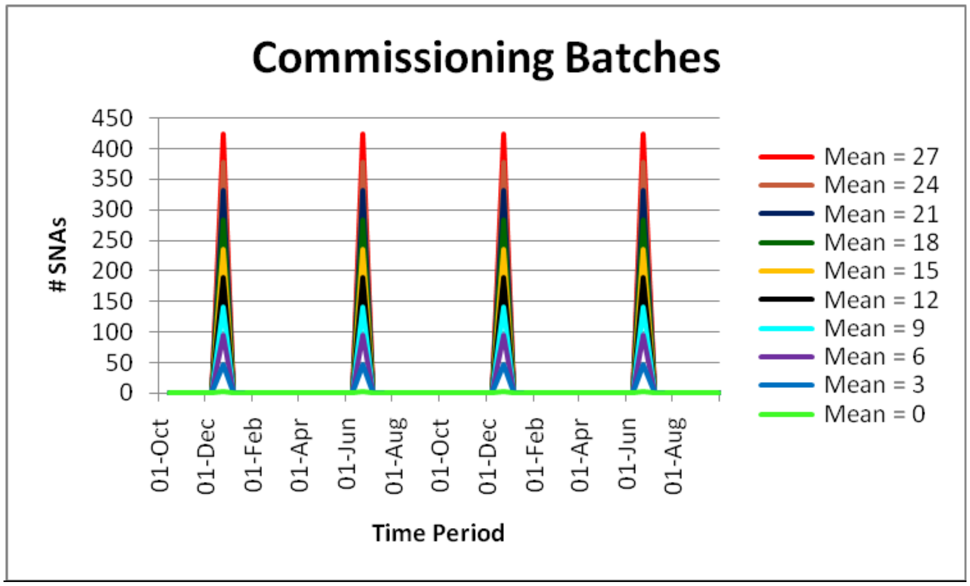

Figure 14. Commissioning Batching

2. A-Pool

The first stage of the optimization model within the undergraduate helicopter program is A-Pool. Newly designated SNAs leave the various commissioning sources in set batches at specific times with the number of students entering the program in approximate equal numbers every six months. The number of students arriving at the start of the program closely matches the definition of the Economic Order Quantity (EOQ) as used in a production facility. However, there are differences in that SNA "ordering" periods are set based on a set time schedule with ordering costs minimal.

This stage acts as a buffer to absorb the sudden influx of these students entering the program and provides a steady flow of students to the IFS training stage. Maximum SNA loading occurs immediately after a batch of students arrives from the

commissioning sources and minimum loading occurs immediately prior to the next batch of students arriving. Numbers of SNAs leaving the A-Pool for the IFS training are relatively constant dependent on the fleet demand, which varies between zero to 27, and range from a minimum of 0.13 students per biweekly period to 34.16 students per biweekly period. A composite chart depicting the model's output of the load and rate of SNAs entering A-Pool is built from the tables contained in the *A-Pool Load* and *A-Pool Rate* worksheets. The resultant graph is depicted in Figure 15.

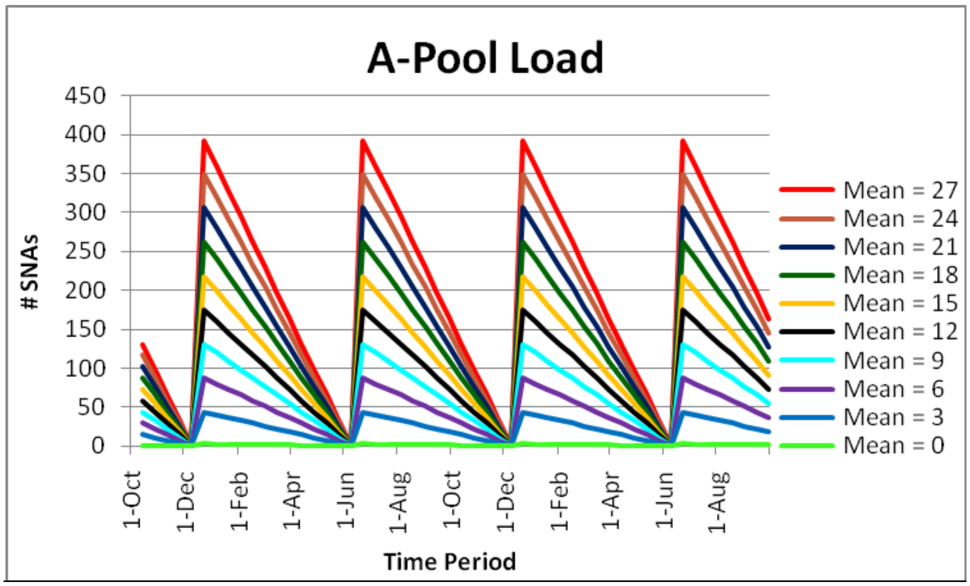

Figure 15. A-Pool Load

3. Introductory Flight Screening (IFS)

The second stage of the optimization model is the Introductory Flight Screening (IFS) training stage. SNAs enter IFS training at a relatively constant rate from A-Pool, as described previously. Student loading within this stage remains consistent based ultimately upon fleet requirements. The biweekly completion rate ranged from 0.12 SNAs to 32.80 SNAs dependent on fleet demand, which varied between zero to 27 indicating that while excess capacity was present within the stage, the model maintained steady flow throughout the supply-chain. A composite chart depicting the model's output

of the load and rate of SNAs entering the IFS training stage is built from the tables contained in the *IFS Load* and *IFS Rate* worksheets. The resultant graph is depicted in Figure 16.

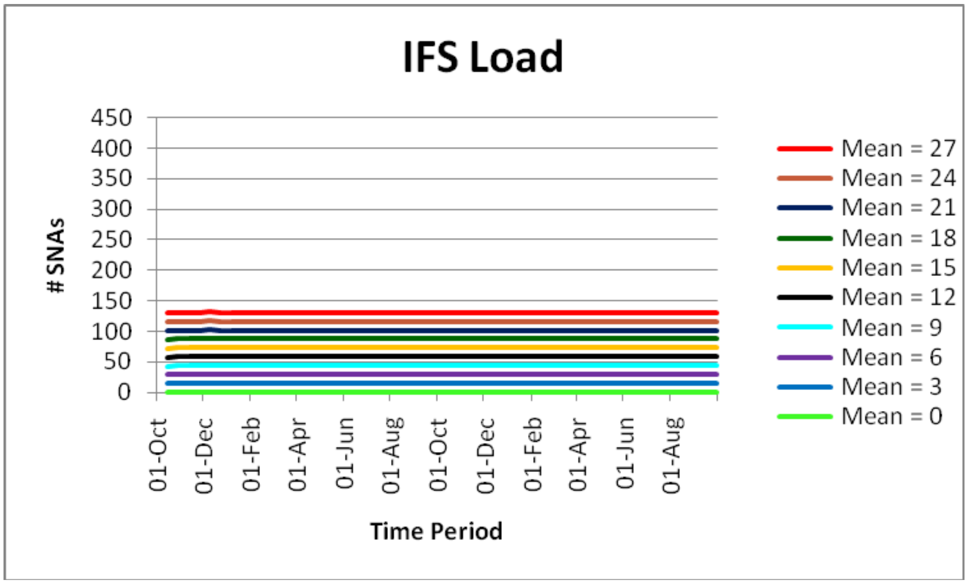

Figure 16. IFS Load

IFS loading remain constant given various student demands. This is expected within this stage and in future stages of the undergraduate training program due to the main objective of the optimization model in minimizing overall costs.

4. B-Pool

The third stage of the optimization model is B-Pool. Students who successfully complete IFS training arrive at B-Pool at a consistent rate, dependent on future fleet demand, and are queued awaiting the start of the next stage of training, API. Within this queue, SNA load remains consistent with numbers of students managed as safety stock designed to protect the supply-chain from variability. Numbers of SNAs leaving B-Pool for API training are relatively constant dependent on fleet demand and range from a minimum of 0.23 students per biweekly period to 31.23 students per biweekly period.

B-Pool does not always need to remain constant and, and load is dependent on the situation, which may cause growth. Such a case can be seen by decreasing of fleet demand during the two-year period while holding commissioning rates constant. For example, decreasing fleet biweekly demand from 23 to 22 pilots results in an overall decrease in program output. This is reflected by decreasing output among all the stages within the program. With constant input, the extra SNAs not required to meet the reduced demand complete IFS training and are held in B-Pool while awaiting the start of API training. A similar case is not seen, however, if the situation is reversed and fleet demand increases from 22 students to 23 students while holding commissioning rates constant. In this scenario, there is no solution possible to meet fleet demand while keeping the overall service rate at 100%. Therefore, changes to the model and to the program must be made to achieve fleet required demand. These changes may include reducing attrition rates through the lowering of standards to allow more students to graduate that would otherwise fail or to transfer SNAs assigned as part of other aviation training pipelines to the helicopter-training pipeline. Assuming predicted fleet demand remains consistent through the two-year period and commissioning rates are allowed to change, a composite chart of depicting the model's output of the load and rate of SNAs entering the B-Pool stage is built from the tables contained in the *B-Pool Load* and *B-Pool Rate* worksheets. The resultant graph is depicted in Figure 17.

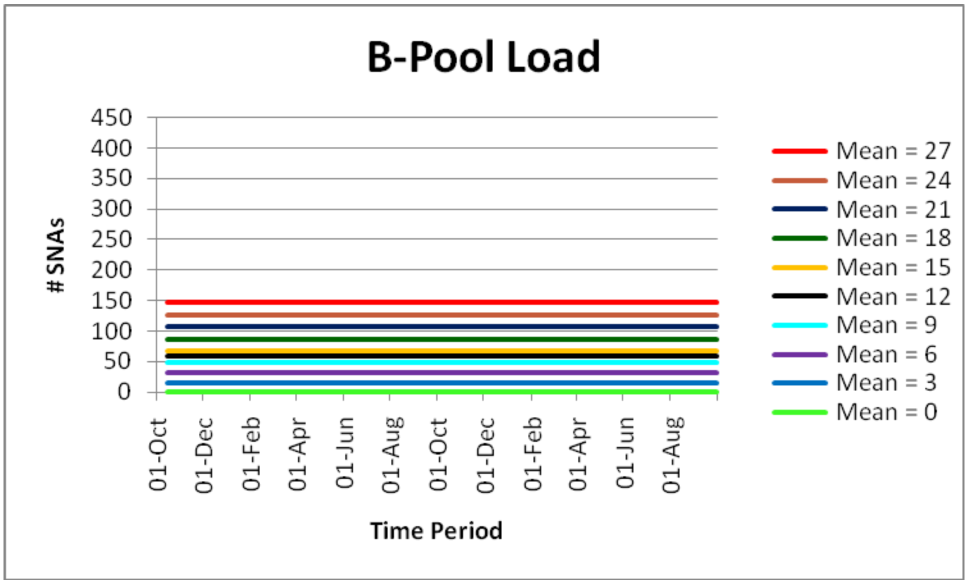

Figure 17. B-Pool Load

5. Aviation Preflight Indoctrination (API)

The fourth stage of the optimization model is Aviation Preflight Indoctrination (API). SNAs enter API training stage at a relatively constant rate from B-Pool, as described previously. Load within this stage remains relatively constant with number of students entering equaling number of students departing either through attrition or completion. Capacity of API, as calculated in Chapter III, is approximately 35.9 students. Although API has a high capacity relative to other stages within the program, the effects of attrition make it the system bottleneck. However, with the addition of an additional stage of IFS training, this may someday shift the bottleneck earlier in the program. If this bottleneck shifted to the IFS training stage, little impact is expected with military flight management under NASC responsible for SNA entry in all training stages throughout the program. However, having a bottleneck early in the program prevents breaks in SNA training at later stages while still allowing managers to control the timing that the SNAs are produced in the future. Because of these timing issues, maximum throughput is not achieved at lower levels of demand with the biweekly completion rates ranging from 0.12 SNAs to 30.35 dependent on fleet demand, which varies between zero

and 27. A composite chart depicting the model's output of the load and rate of SNAs completing API training stage is built from the tables contained in the *API Load* and *API Rate* worksheets. The resultant graph is depicted in Figure 18.

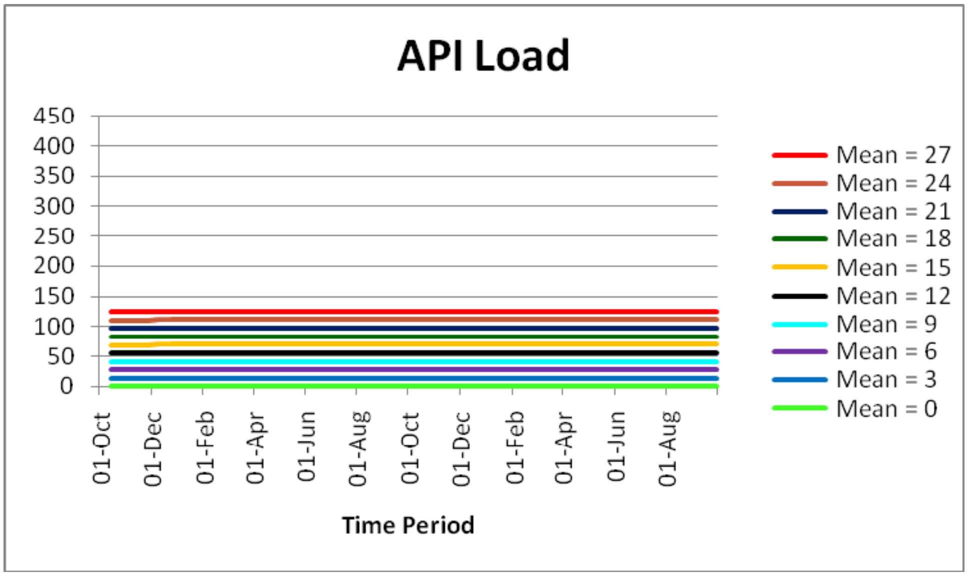

Figure 18. API Load

6. C-Pool

The fifth stage of the optimization model is C-Pool. Students who successfully complete API training arrive at C-Pool at a consistent rate, dependent on future fleet demand, and are queued awaiting the start of the next stage of training, Primary Flight Training. Within this queue, SNA load remains consistent with numbers of students managed as safety stock designed to protect the supply-chain from variability. This number of students is set by the flight manager. Numbers of SNAs leaving C-Pool for the API training range from a minimum of 0.12 students per biweekly period to 30.39 students per biweekly period depending on level of fleet demand. A composite chart depicting the model's output of the load and rate of SNAs entering C-Pool stage is built from the tables contained in the *C-Pool Load* and *C-Pool Rate* worksheets. The resultant graph is depicted in Figure 19.

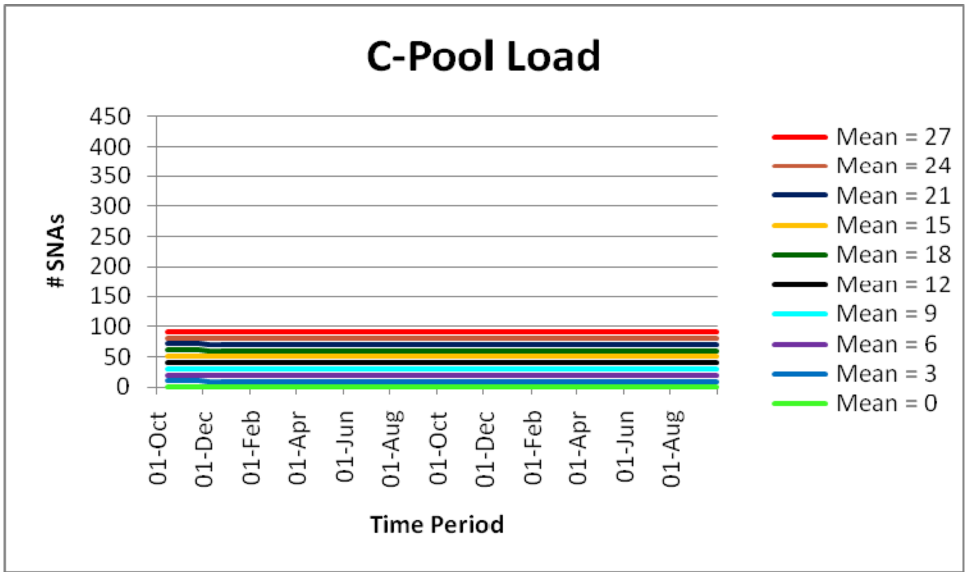

Figure 19. C-Pool Load

7. Primary Flight Training

The sixth stage of the optimization model is Primary Flight Training. SNAs enter the Primary Flight Training stage at a relatively constant rate from C-Pool, as described previously. Load within this stage remains relatively constant with number of students entering equaling number of students departing either through attrition or completion. Capacity of Primary Flight Training, as calculated in Chapter III, is approximately 31.21 students. However, maximum throughput was never achieved. The biweekly completion rate ranged from 0.10 SNAs to 27.92 SNAs dependent on fleet demand, which varies between zero and 27 indicating that while excess capacity was present within the stage, the model maintained steady flow throughout the supply-chain.

A composite chart depicting the model's output of the load and rate of SNAs completing API training stage is built from the tables contained in the *Primary Load* and *Primary Rate* worksheets. The resultant graph is depicted in Figure 20.

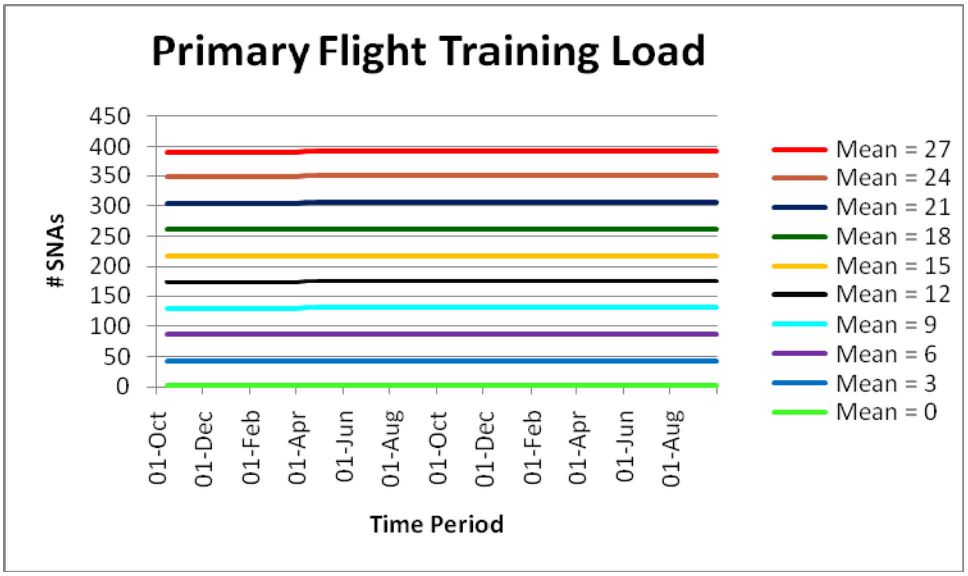

Figure 20. Primary Flight Training Load

8. D-Pool

The seventh stage of the optimization program is D-Pool. Students who successfully complete Primary Flight Training arrive at D-Pool at a consistent rate, dependent on future fleet demand, and are queued awaiting the start of the next stage of training, Advanced Rotary Flight Training. As with C-Pool, in this queue, within this queue, SNA load remains consistent with numbers of students managed as safety stock designed to protect the supply-chain from variability. This number of students is set by the flight manager. However, as students approach the end of the undergraduate helicopter training program, less variability exist, therefore less student load exists within D-Pool. Numbers of SNAs leaving D-Pool for the Advanced Rotary Flight Training range from a minimum of 0.11 students per biweekly period to 28.12 students per biweekly period depending on level of fleet demand. A composite chart depicting the model's output of the load and rate. SNAs within the D-Pool stage are built from the tables contained in the *D-Pool Load* and *D-Pool Rate* worksheets. The resultant graph is depicted in Figure 21.

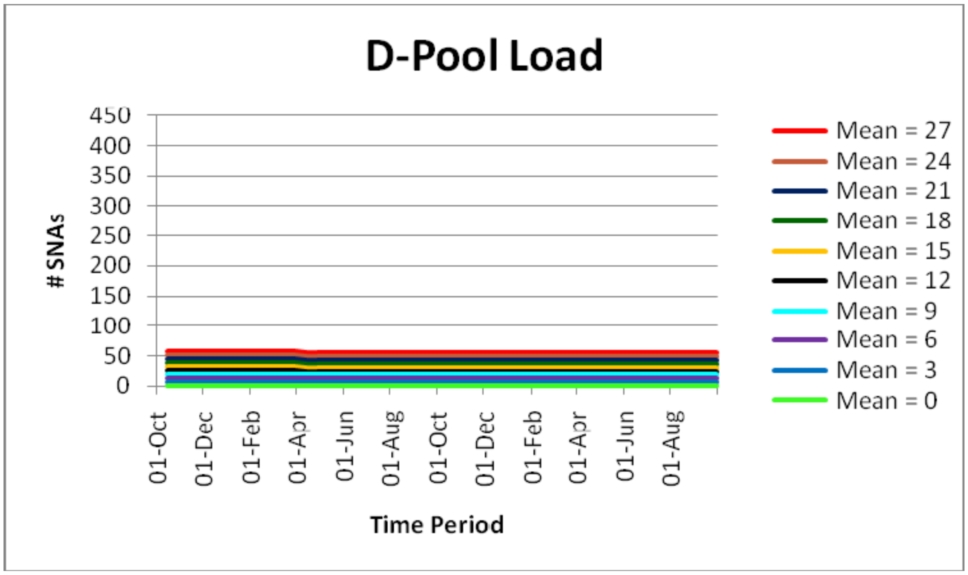

Figure 21. D-Pool Load

9. Advanced Rotary Flight Training

The eighth stage of the optimization model is the Advanced Rotary Flight Training. SNAs enter the Advanced Rotary Flight Training stage at a relatively constant rate from D-Pool, as described previously. Load within this stage remains relatively constant with number of students entering equaling number of students departing either through attrition or completion. Capacity of this stage of training is calculated in Chapter III at approximately 31.21 students. The model simulated biweekly completion rates ranging from 0.11 SNAs to 27.27 representing a range of zero to 27 pilots required on a biweekly basis by the fleet squadrons indicating that while excess capacity is present within the stage, the model maintained steady flow throughout the supply chain. A composite chart depicting the model's output of the load and rate of SNAs completing Advanced Rotary Flight Training stage is built from the tables contained in the *Advanced Load* and *Advanced Rate* worksheets. The resultant graph is depicted in Figure 22.

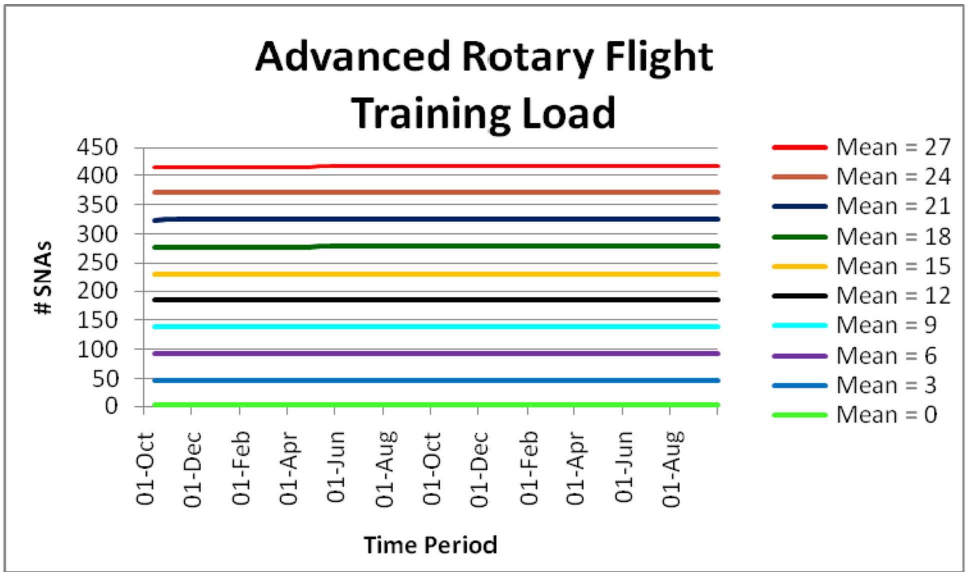

Figure 22. Advanced Rotary Flight Training Load

10. E-Pool

The ninth and final stage of the program is E-Pool. Students who successfully complete Advanced Rotary Flight Training arrive at E-Pool at a consistent rate, depending on future fleet demand, and are queued awaiting the winging ceremony and permanent change of station and transfer to the various Fleet Replacement Squadrons (FRS). As with C-Pool and D-Pool, in this queue, a small number of SNAs are held as safety stock, protecting the supply-chain from variability. However, at this stage, little variability exist, therefore, less student load exists within E-Pool as the previous queues. Numbers of SNAs leaving E-Pool range from a minimum of 0.11 students per biweekly period to 27.92 students per biweekly period depending on level of fleet demand. A composite chart depicting the model's output of the load and rate of SNAs entering the E-Pool stage is built from the tables contained in the *E-Pool Load* and *E-Pool Rate* worksheets. SNAs within the E-Pool stage are built from the tables contained in the *E-Pool Load* and *E-Pool Rate* worksheets. The resultant graph is depicted in Figure 23.

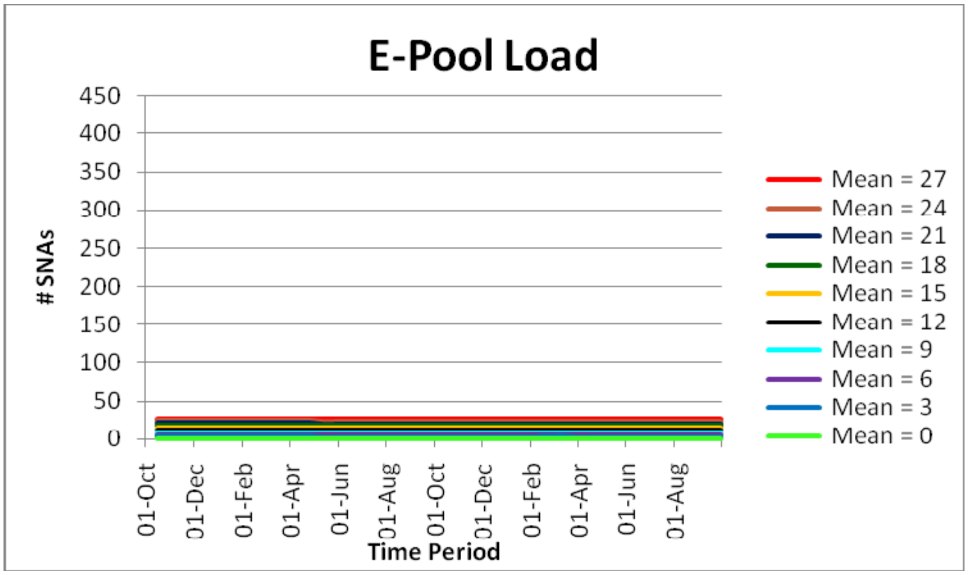

Figure 23. E-Pool Load

11. Service Rates

Service rate within the undergraduate helicopter-training program is defined as the number of pilots produced at the end of the program as a percentage of pilots demanded by fleet squadrons. Within the model, as fleet demand increased from zero to 27 pilots, capacity of the system was never exceeded. Service rates between biweekly timer periods fluctuated above and below fleet demand under production in one period and over production in another. However, on average, at the end of the year, the resultant service rate was 100% indicating fleet demand was met, as depicted in Figure 24.

As discussed in the Commissioning Batching, changes to fleet demand within the two-year time period is a possibility with many unknowns affecting the system. Increases or decreases in fleet demand from one fiscal year to the next result in overproduction and underproduction of students within the two-year time period. For example, increasing the number of pilots required from 22 to 23 at the end of the first fiscal year results in an overproduction of winged pilots during the first year followed by an underproduction during the second year. A similar process occurs when reduction of

fleet demand reducing the number of required pilots from 23 to 22 with an underproduction of winged pilots produced in the first year followed by an overproduction in the second year.

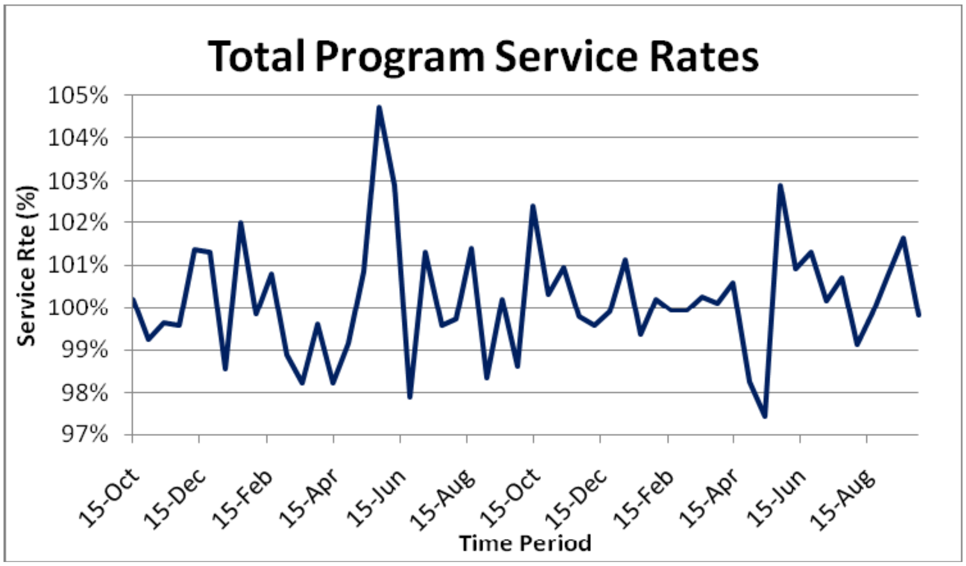

Figure 24. Service Rate

12. Total Variable Costs

The main purpose of the optimization model was to minimize variable costs of the entire program from the start of the program at A-Pool through the end of the program at E-Pool. Total variable costs ranged from a minimum of $25,804 to $7,788,234 per two-year (i.e., 52 biweekly periods) dependent on fleet demand. Total variable costs per student ranged from a minimum of $267,831, a maximum of $279,301 and an average of $268,495.

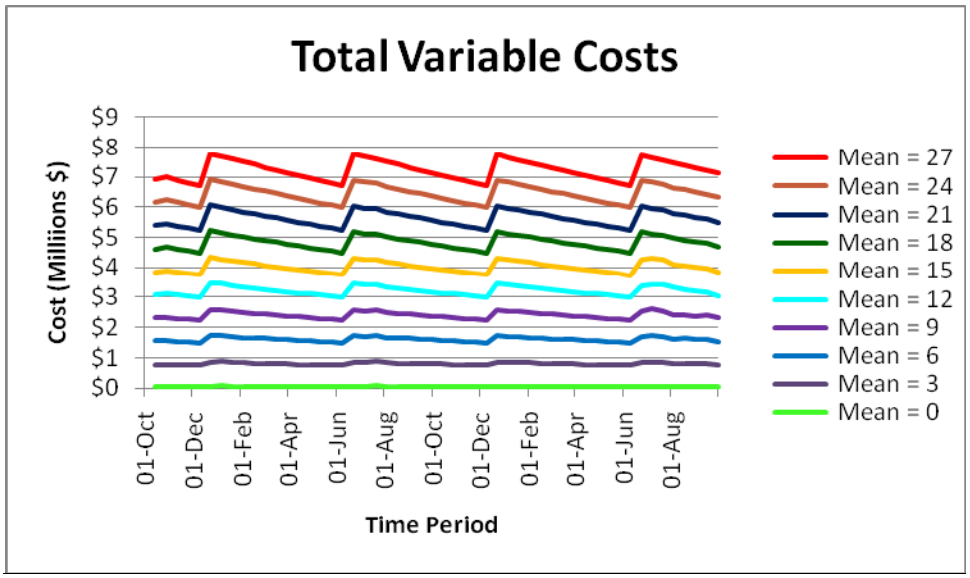

Figure 25. Total Variable Costs

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The purpose of this study was to develop a model-based approach for generating an optimal training plan for mangers within the undergraduate helicopter-training program. Costs, capacities and attrition rates within each stage were addressed and based on historical information and assumptions stages. However, as with all models, this is only a simplified version of a more complex reality and is but one of many tools that flight managers may use.

In the model, the optimized outcome is not the sum of the total optimized results of each individual stage. If optimization of each stage were to occur, student throughput would be at maximum capacity for each stage to avoid incurring holding costs of students. However, in each of the training stages, the capacity was not strained. Instead, the model maintained steady flow of students throughout the entire system in a push-pull method of supply-chain management with fleet demands pulling students at completion of the program driving commissioning sources to push students entering the start of the program.

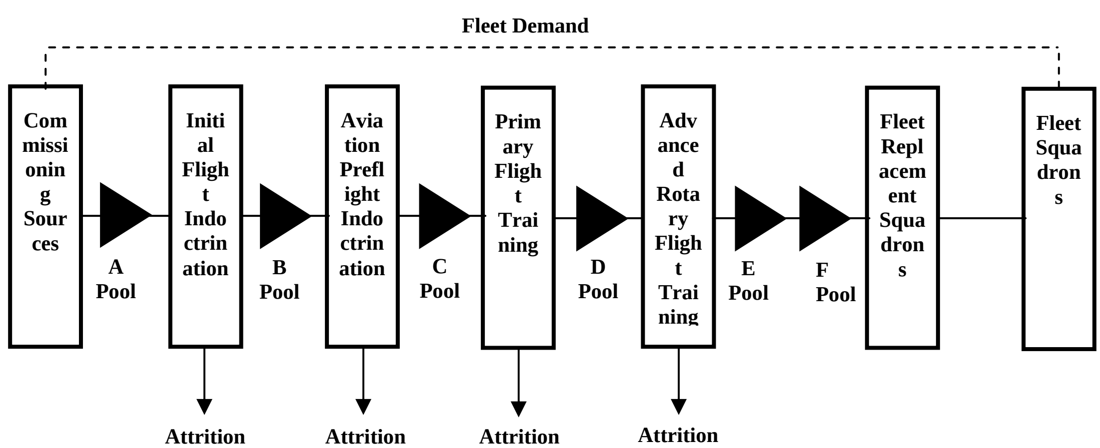

Figure 26. Helicopter Pilot Training Supply Chain

Through the use of a user defined inputs (i.e., batching, capacity, loading, and attrition), the model can easily be changed and the simulation rerun to determine effects such changes to the system would incur compared to the current baseline model prior to implementation of such plans.

Model simulation tested the system from zero to 27 pilots to represent the current expected scale of demand from the fleet squadrons with the maximum capacity of this system being 30.2, as discussed in Chapter III. IFS was identified as the bottleneck of the system with capacity of 34.96 resulting in the maximum demand allowable by the model of 30.2. Once this limit is reached, the request for additional students without addressing bottleneck issues drives up costs exponentially while simultaneously driving down service rates. This effect, depicted in Figure 25, illustrates the effects of increasing pilot demand on service rates and total variable costs and Figure 27 depicts the effects of increasing pilot demand on service rates and total variable costs per SNA.

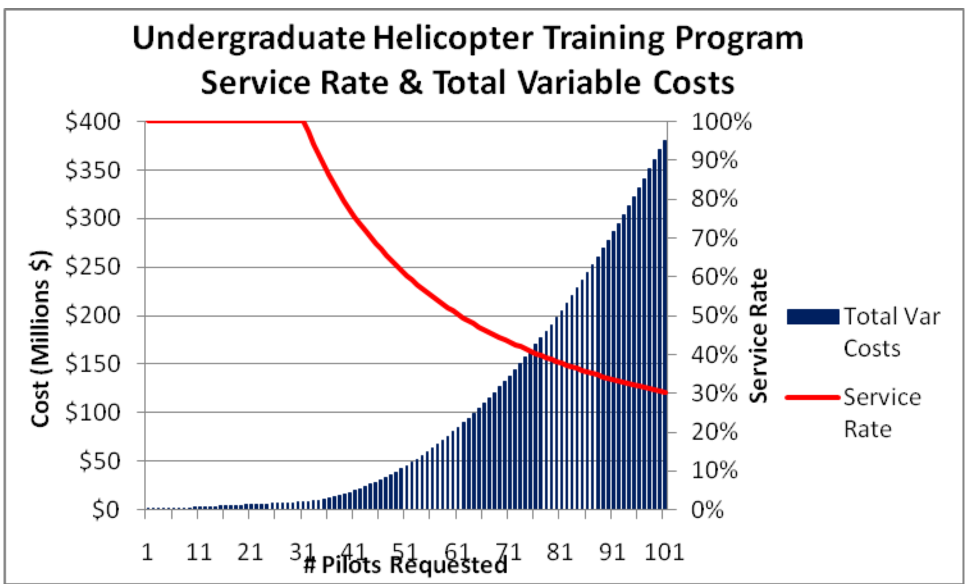

Figure 27. Number of Pilots Vs. Total Variable Costs and Service Rates

Results of the model baseline simulation, as described in Chapter IV, identify four main cost drivers: 1) Costs associated with the number of SNAs; 2) Costs for uncertainty of demand; 3) Costs linked with holding SNAs in the various pools; and 4) Costs linked

with SNAs changing duty stations from one location to another. Each of these cost drivers can be analyzed to further minimize resultant costs below that of the baseline model.

B. RECOMMENDATIONS

Based on the analysis and conclusions, previously discussed, the following recommendations are made to improve these four areas that will save costs.

1. Demand
2. Variability
3. Inventory
4. Transfers

Overall variable cost savings implementing reduction in these four areas are simulated through computational experimentation, as described in Chapter IV. The results of these variable cost savings simulations as applied to the based model are depicted in Figure 28 and are described in detail in sections one through four.

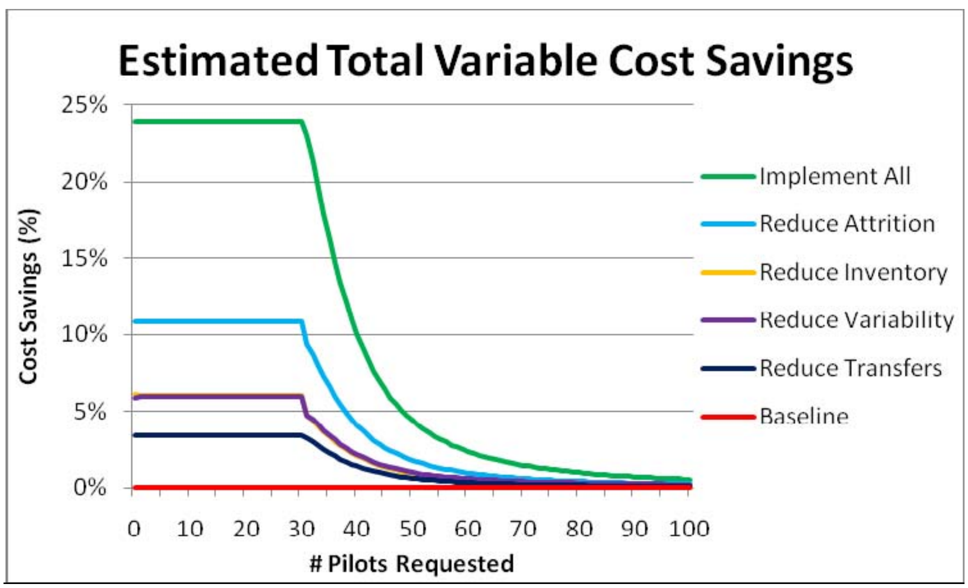

Figure 28. Estimated Total Variable Cost Savings

1. Reduce Demand

Reduction of the number of SNAs trained, thereby reducing total overall variable costs, can be accomplished through two methods, reducing the attrition rates and reducing fleet demand.

a. Reduce Attrition Rates

Two methodologies that can be used to reduce attrition rates are an arbitrary reduction in the number of SNA attrition rate or an implementation of a more stringent screening process for SNA. An arbitrary reduction in the attrition rate is a myopic option and is not a valid long-term option. By allowing poorly performing SNA to earn their wings just to meet fleet demand will allow less than qualified pilots into the fleet that may later become liabilities to the fleet squadrons that receive them. Additional costs that may be incurred include supplemental training requirements due to poor performance, maintenance cost for damage incurred due to the pilot's negligence or the possible injury or death because of pilot error. This option comes at a tradeoff of quantity and quality. Historically, this method had been used in the past to meet fleet demands, but its use has been controversial and therefore it is not a valid option.

The implementation of a more stringent preselection screening process is a much better option to reduce attrition rates. One method to select SNA is based on the Aviation-Selection Test Battery (ASTB). The ASTB is a battery of test that examines math skills, reading skills, mechanical comprehension, spatial apperception, aviation and nautical knowledge. The primary focus of the ASTB is to evaluate the mental capability of the candidates. The ASTB could combine both mental and physical tests to evaluate how a candidate would perform physiologically.

In addition to using an enhanced ASTB, midshipmen attending USNA and other ROTC units can be screened earlier in their training to identify potential SNA candidates. Midshipmen can be evaluated on the potential for aviation while on midshipmen cruises during the summer. Midshipmen cruises are used to provide the midshipmen with an introduction into the Navy's operational fleet. First class cruises are

more focused on student's service selection desires. This period can be used to evaluate the midshipmen with training simulators and flights that already exist in the fleet to begin the screening process for future SNA. Changing this parameter in the model and rerunning the simulation resulted in a 10.9% of total variable cost savings, as shown in Figure 27. However, additional training and evaluation come with added costs, which increase as the attrition rates decrease. A cost-benefit analysis is required to determine if this option is beneficial.

b. Reduce Fleet Demand

A method to reduce fleet demand without an actual decrease to the number of pilots in the squadron is to increase the length of tour in the squadron from the current 36 months to either 48 or 60 months for first tour pilots. By increasing the tour length, the squadrons will keep the experience of it pilots for a longer time while, and as a result, may reduce operational training cost and PCS costs within the Navy, as a whole.

An example of reduced fleet demand as a result of increased tour length is depicted below using Little's Law, which is explained as: the long-term average number of pilots in a squadron L is equal to the long-term average arrival rate, λ, multiplied by the long-term average time a pilot is in the squadron, W; or expressed algebraically: $L = \lambda W$. Where λ_3 is equal to the arrival rate based on a 3-year order and λ_4 is equal to the arrival rate based on 4-year order.

$L = \lambda * W$, where L is constant
$L = \lambda_3 * 3$ years and $\lambda_4 * 4$ years
$\lambda_3 * 3$ years = * $\lambda_4 * 4$ years.

Therefore,

$\lambda_4 / \lambda_3 = 3/4$.

For example, using the current baseline demand for pilots of 22 per two-week period, we can calculate fleet demand would decrease to 16.5 if the pilot tours were extended to four years; additionally, five-year orders will decrease the number of pilots demanded to 13.2.

$$\lambda_4 / \lambda_3 = 3/4$$
$$\lambda_4 / 22 = 3 / 4$$
$$\lambda_4 = 22*3/4$$
$$\lambda_4 = 16.5$$

Based on model calculations, average cost per students remains relatively constant at approximately $268,500, regardless of the number of students in the program. Therefore, the reduction in SNAs requiring training results in a cost savings of $1,476,750 within the undergraduate pilot training program. This becomes more evident when comparing cost savings if fleet tours were extended to 60-month orders. With required number of pilots required reduced by 2/3 from 22 pilots to that of 13.2 results in overall variable cost savings of $2,362,800. This option, however, is shortsighted due to its potential impact on other billets that need to be filled by the first tour pilots leaving their operational squadrons. Additionally traditional career paths will have to be adjusted due to the decrease in possible billets that are available to be filled. A cost-benefit analysis is required to determine if this option is beneficial.

2. Reduce Variability

Reduction of the variability of the system can be accomplished through reducing batch sizes and increasing the ordering of students entering the program from the various commissioning sources. Utilizing just-in-time inventory through level loading practices reduces the fluctuations in student loads of A-Pool as SNAs wait to enter the IFS training stage, as shown in Figure 29.

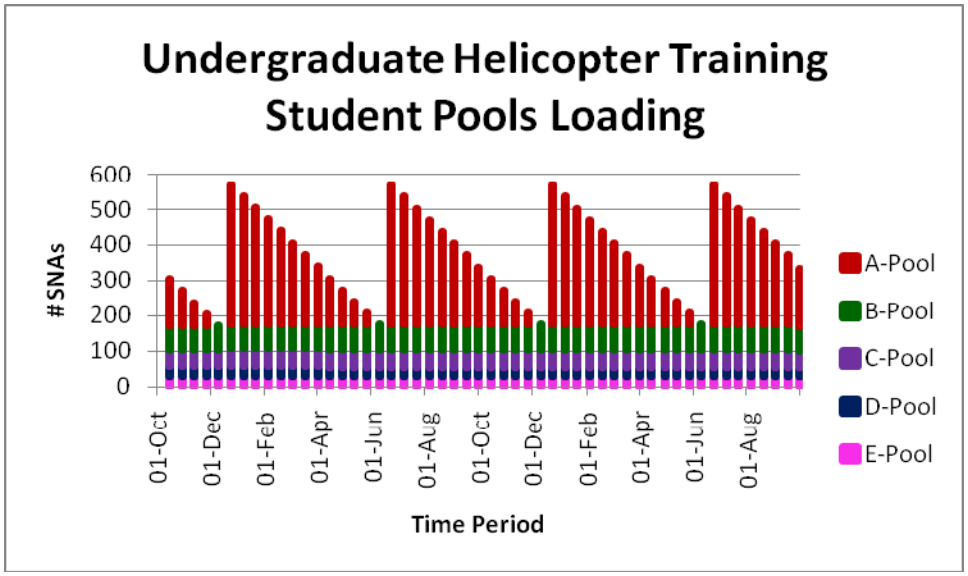

Figure 29. Student Pool Loads

This level loading practice can be accomplished through a form of delayed entry program already implemented by the Navy in other high cost training programs such enlisted boot camp. In this delayed entry program, the SNA's first set of official orders would include a specific start date for IFS training to begin. This option may have larger impacts in the Navy if coupled with use of a delayed commissioning process. With known specific start dates, time spent prior to beginning aviation training may be spent on other goals, such as continuing graduate education. Through this level loading, all other variables remaining constant, SNA loading in A-Pool can be reduced to zero resulting in a reduction of the average wait time of students from 46 weeks to 22 weeks. This results in a 52% reduction of total nontraining wait time of SNAs within the program. Changing this parameter in the model and rerunning the simulation resulted in a 5.9% of total variable cost savings, as shown in Figure 27.

3. Reduce Inventory

Reduction in the variability of the system has an added benefit in allowing flight managers to reduce inventory held as safety stock, thereby, reducing total program holding costs. Safety stock is maintained in various pools within the system to buffer

against both over and under production between each individual stage within the program and against increases and decreases in demand from outside of the program. From operations management, adequate safety stock can be calculated using the following equation:

$$\text{Safety Stock} = z*(\mu_L*\sigma_D^2 + \mu_D^2*\sigma_L^2)^{1/2}$$

Variables used in this equation are as follows.

z	Required service rate calculated as NORMSINV(Service Rate)
μ_L	Average Lead Time
μ_D	Average Demand
σ_L	Standard Deviation of Lead Time
σ_D	Standard Deviation of Demand

Required service rates are set by military planners and are dependent on the acceptable amount of risk. Average lead time varies between stages with commissioning sources providing SNAs to the program every 6 months (i.e., 13 periods), IFS and API providing students to B-Pool and C-Pool every one week (i.e., .5 periods), and Primary Flight Training and Advanced Rotary Flight Training providing SNAs to D-Pool and E-Pool every two weeks (i.e., one period). Average demand for each stage is dependent on fleet demand at the end of the program, taking into account attrition rates of each stage. Standard deviation of lead time accounts for uncertainty of SNAs not completing a training stage at the predetermined set time due to delays from weather, medical, academics, and maintenance. Delays are also influenced on length of the training stage in which the SNA is participating (i.e., longer training stages incur more chances of experience delays than do shorter stages). Assuming variability of delays are the same regardless of the reason, approximate values of the standard deviation of lead time can be determined. Finally, standard deviation of demand is given based on calculations as described in Chapter III.

Using these description of variables, safety stock for each pool using the baseline model can be calculated.

$$\text{Stock}_{\text{A-Pool}} = z * (13 * 0.5^2 + 0^2 * \mu_D^2)^{1/2} = z * (3.25 + 0 * \mu_D^2)^{1/2} = z * 1.80$$
$$\text{Stock}_{\text{B-Pool}} = z * (.5 * 0.5^2 + .53^2 * \mu_D^2)^{1/2} = z * (.125 + .28 * \mu_D^2)^{1/2}$$
$$\text{Stock}_{\text{C-Pool}} = z * (.5 * 0.5^2 + .23^2 * \mu_D^2)^{1/2} = z * (.125 + .05 * \mu_D^2)^{1/2}$$
$$\text{Stock}_{\text{D-Pool}} = z * (1 * 0.5^2 + .62^2 * \mu_D^2)^{1/2} = z * (.25 + .38 * \mu_D^2)^{1/2}$$
$$\text{Stock}_{\text{E-Pool}} = z * (1 * 0.5^2 + .64^2 * \mu_D^2)^{1/2} = z * (.25 + .41 * \mu_D^2)^{1/2}$$

For example, for an average fleet demand of 22 students using attrition rates for as discussed in Chapter III, safety stock of the various pools are calculated with typical service rates, as depicted in Table 10.

Table 10. Safety Stock Example ($\mu_{D = }22$)

	Service Rate					
	75%	80%	85%	90%	95%	100%
A-Pool	0.24	0.30	0.37	0.45	0.58	2.81
B-Pool	9.19	11.47	14.12	17.46	22.41	108.20
C-Pool	3.90	4.87	6.00	7.41	9.52	45.95
D-Pool	9.54	11.90	14.66	18.13	23.27	112.33
E-Pool	9.51	11.87	14.61	18.07	23.19	111.96

Baseline model annual service rates program completion was approximately 100%, however, within the year, biweekly service rates were 97.5 percent. All other variables remaining constant, model outputs indicate that implementation of this COA would introduce a small safety stock to A-Pool thus increasing the level from zero to 3.5. Safety stock for B-Pool would be increased from zero to 23.0. Safety Stock for C-Pool would be reduced from 74.0 to a new value of 10.1. Safety stock for D-Pool would be reduced from 45.4 to a new value of 26.9. Finally, safety stock for E-Pool would be increased from 22.0 to a new level of 27.6. This results in a 48% reduction of overall

numbers of SNAs waiting in the Pools within the program. Changing this parameter in the model and rerunning the simulation resulted in a 6.0% of total variable cost savings, as shown in Figure 28.

4. Reduce Transfers

Reduction of total transfer costs can be accomplished through the reduction or elimination of PCS moves between various stages of the program. These moves occur during the transition between API at NAS Pensacola and Primary Flight Training at NAS Corpus Christi, as well as between Primary Flight Training at NAS Corpus Christi and Advanced Rotary Flight Training at NAS Whiting Field. To eliminate costs for these PCS moves, student helicopter pilots must be selected no later than the completion of API training. If implemented, SNAs selected for helicopter training would incur no PCS costs, with Primary Flight Training conducted at NAS Whiting Field.

This type of program is already in use by the surface warfare community with newly commissioned officers receiving first set of orders to type of ship they will first serve aboard within the fleet. Tailoring such a program towards the aviation community would involve matching students with platforms during orders from the various commissioning sources prior to entry into the aviation-training program. However, implementation of this program may have negative effects resulting in increased attrition rates later in the process. Therefore, as previously discussed with reducing attrition rates, this risk must be mitigated through a more stringent preselection process to augment or replace the current ASTB currently used. If such a program were to be implemented, it would result in a cost savings of 100% of transfer costs of the undergraduate helicopter-training program and have similar benefits of other training pipelines. Changing this parameter in the model and rerunning the simulation resulted in a 3.4% of total variable cost savings, as shown in Figure 27.

C. SUGGESTIONS FOR FUTURE RESEARCH

The modeling approach and simulation of the undergraduate helicopter-training program reveals possible potential future research topics. Further research is required to be conducted to validate the previous recommendations to include the following.

1. Refine the model to account for variations of variables that increase students time to train (i.e., weather, medical and maintenance)
2. Increase the scope of model to include pilot training flow through the completion of the FRS and final delivery of qualified pilots to the fleet squadrons.
3. Develop a test of batteries to augment or replace ASTB that provides a more thorough and holistic (i.e., mental, medical and physical) screening of perspective SNAs prior to selection in order to reduce attrition rates within the aviation training program and allow for the initiation of an early platform selection process.
4. Conduct a cost-benefit analysis of selecting an aviation platform early and tailoring certain phases of training to reflect selection (i.e., if selected helicopter, then do not need aerobatics).
5. Conduct a cost-benefit analysis of increasing the length of fleet tours from 36 months to 48 or 60 months.

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APPENDIX A. HOLDING COST CALCULATIONS

Table 11. Holding Costs Computation

Holding Costs (NAS Pensacola / NAS Whiting Field)	**Daily Costs (O–1)**	**Daily Costs (O–2)**
Base Pay	$90	$118
Basic Allowance for Subsistence (BAS)	$7	$7
Basic Allowance for Housing (BAH)	$34	$34
Fly Pay*	$4	$4
Retired Pay Accrual	$30	$40
Medicare-Eligible Retiree Health Care Accrual	$25	$25
Totals*	$190	$230

Holding Costs (NAS Corpus Christi)	**Daily Costs (O–1)**	**Daily Costs (O–2)**
Base Pay	$90	$118
Basic Allowance for Subsistence (BAS)	$7	$7
Basic Allowance for Housing (BAH)	$48	$48
Fly Pay*	$4	$4
Retired Pay Accrual	$30	$40
Medicare-Eligible Retiree Health Care Accrual	$25	$25
Totals*	$204	$242

*Note: SNA fly pay starts during primary stage of training

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APPENDIX B. HELICOPTER TRAINING PROGRAM SYLLABI

A. INTRODUCTORY FLIGHT SCREENING (IFS)

Table 12. Introductory Flight Screening (IFS) Syllabus (From Chief of Naval Air Training (CNATRA) Instruction 3501.1B Introductory Flight Screening (IFS) Program)

Event	Remarks	Syllabus Events			
		Ground	Preflight	Flight Time	Postflight
Flight Equipment Issue					
Ground Stage 1		10.00			
Ground Stage 2		10.00			
Flight 1			0.50	0.50	0.50
Flight 2			0.50	1.00	0.50
Flight 3			0.50	1.25	0.50
Flight 4			0.50	1.25	0.50
Flight 5			0.50	1.25	0.50
Flight 6			0.50	1.25	0.50
Flight 7			0.50	1.25	0.50
Flight 8			0.50	1.25	0.50
Flight 10	Check Flight		0.50	1.50	0.50
Flight 9	Solo		0.50	1.00	0.50
Ground Stage 3		10.00			
Flight 11			0.50	1.25	0.50
Flight 12	Solo		0.50	0.50	0.50
Flight 13	Solo		0.50	1.00	0.50
Flight 14			0.50	1.25	0.50
Flight 15			0.50	1.25	0.50
Flight 16	Night		0.50	1.25	0.50
Flight 17	X-Country		0.50	1.75	0.50
Flight 18	Night X-Country		0.50	1.75	0.50
Flight 20	Check Flight		0.50	1.75	0.50
Flight 19	X-Country Solo		0.50	1.75	0.50
		30.00	10.00	25.00	10.00

B. PRIMARY FLIGHT TRAINING

Table 13. Primary Flight Training Syllabus (From Chief of Naval Air Training (CNATRA) Instruction 1542.140D; Primary Multi-Service Pilot Training System Curriculum)

Flight / Events	CPT		SIM		T-34C			
					Dual		Solo	
	Flts	Hrs	Flts	Hrs	Flts	Hrs	Flts	Hrs
Cockpit Procedure	5	6.5						
Day Contact					16	29.2	4	6.9
Day Contact Check					1	2.0		
Night Contact					2	3.0		
Basic Instruments			7	9.1	3	4.5		
Radio Instruments			9	11.7	5	9.0		
Instrument Navigation			10	13.0	4	8.0		
Instrument Check					1	2.0		
Day Navigation					2	3.2		
Night Navigation					2	3.2		
Basic Formation					5	10.5	1	1.5
Cruise Formation					3	6.0		
Totals	5	6.5	26	33.8	44	80.6	5	8.4

C. ADVANCED ROTARY FLIGHT TRAINING

Table 14. Advanced Rotary Flight Syllabus (From Chief of Naval Air Training (CNATRA) Instruction 1542.156B; Advanced Helicopter MPTS Curriculum)

Flight / Events	CPT		SIM		TH-57B/C Dual		TH-57B/C Solo	
	Flts	Hrs	Flts	Hrs	Flts	Hrs	Flts	Hrs
Procedures Trainer	5	6.5						
Contact 'B'					13	22.5	1	1
Contact 'B' Safe-for-Solo Check Ride					1	1.2		
Contact 'C'			1	1.3	4	6.0		
Contact 'C' Safe-for-Solo Check Ride					1	1.2		
Night Contact 'C'					2	3.0		
Basic Instruments			5	6.5	6	10.2		
Basics Instruments Check Ride					1	1.5		
Emergency Procedures			2	2.6				
Radio Instruments			18	23.4	8	15.2		
Airways Navigation			2	2.6				
Instrument Navigation					4	8.0	1	2
Instrument "Safe for Solo" Check Ride					1	1.8		
Day Navigation					3	5.1	1	1.7
Night Navigation					1	1.7		
Low-Level Navigation					5	7.5		
Formation					3	6.0		
Combat Cruise Formation					1	1.8		
Day Tactical					3	4.5		
Shipboard/SAR			2	2.6	3	2.5		
Night Vision Device			1	1.3	5	8.5		
Totals	5	6.5	31	40.3	65	108.2	3	4.7

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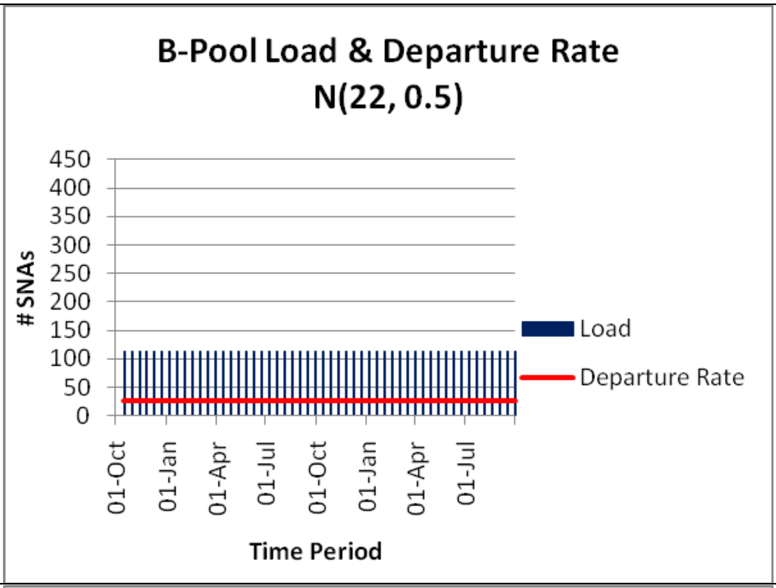
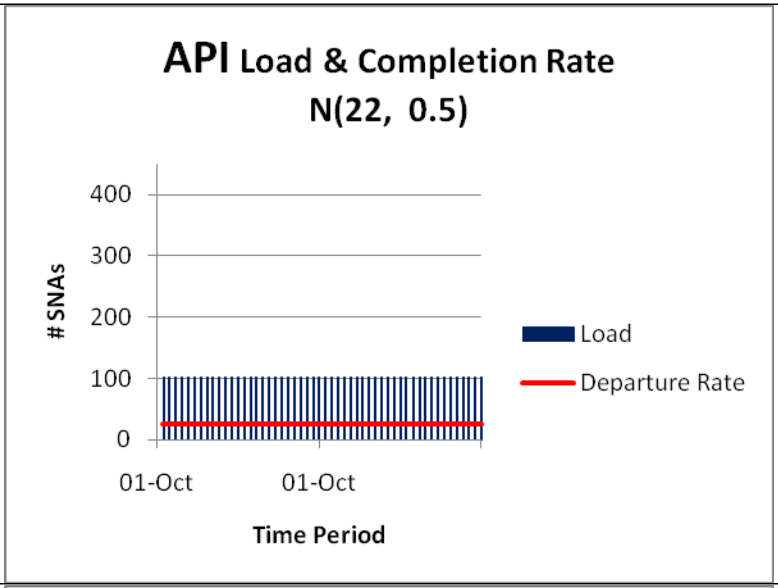
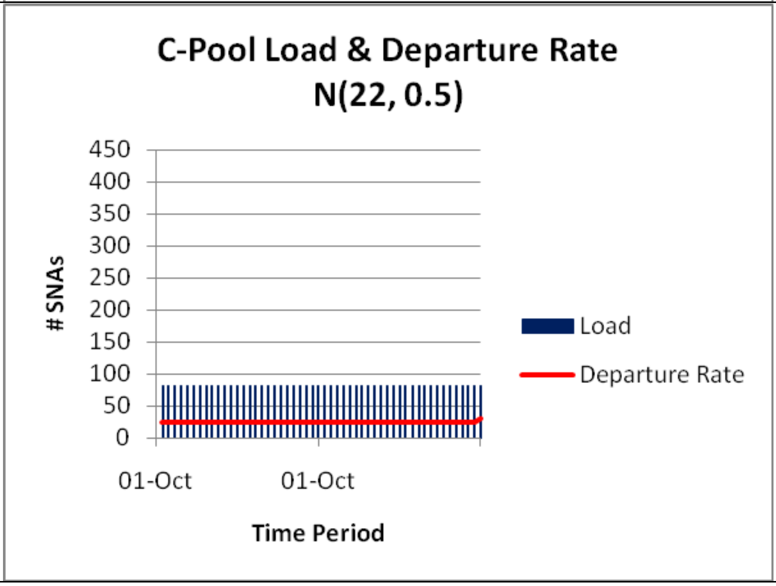
APPENDIX C. OPTIMIZATION MODEL EXAMPLE OUTPUT

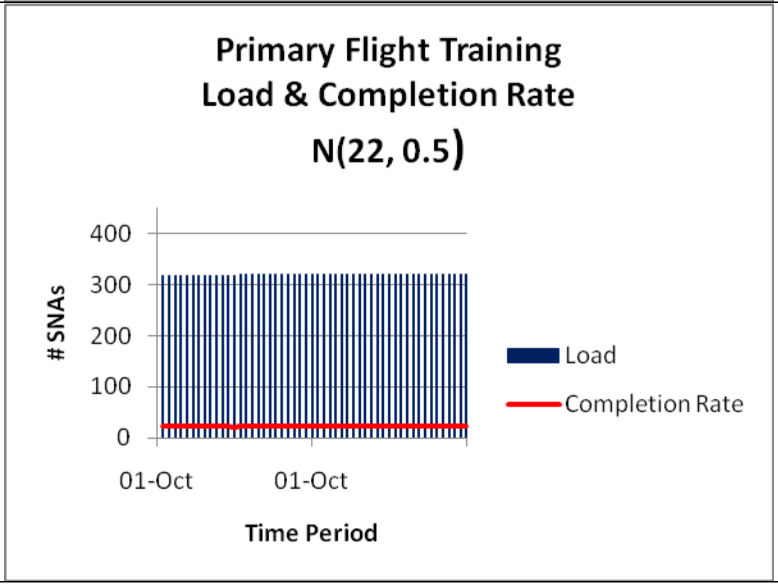
Appendix C contains a sample of the output charts produced by the optimization model based on a mean fleet demand of 22 pilots.

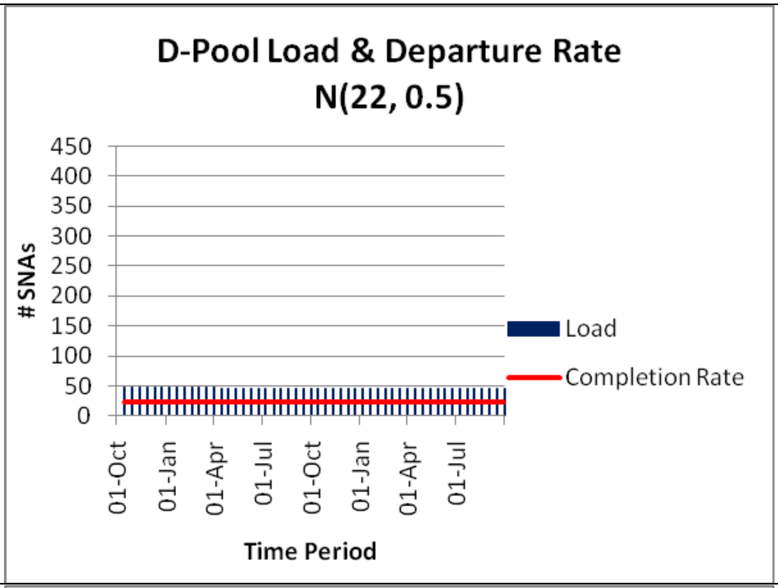

Fleet Demand
N(22, 0.5)
# Pilots Requested
35
30
25
20
15
10
5
0
01-Oct
01-Dec
01-Feb
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
01-Feb
01-Apr
01-Jun
01-Aug
Time Period
Max
Average
Min
Commissioned SNAs
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Dec
01-Feb
01-Apr
01-Jun
01-Aug
01-Oct
01-Dec
01-Feb
01-Apr
01-Jun
01-Aug
Time Period
Max
Average
Min
A-Pool Load & Departure Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Oct
Time Period
Load
Departure Rate
IFS Load & Completion Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Oct
Time Period
Load
Completion Rate

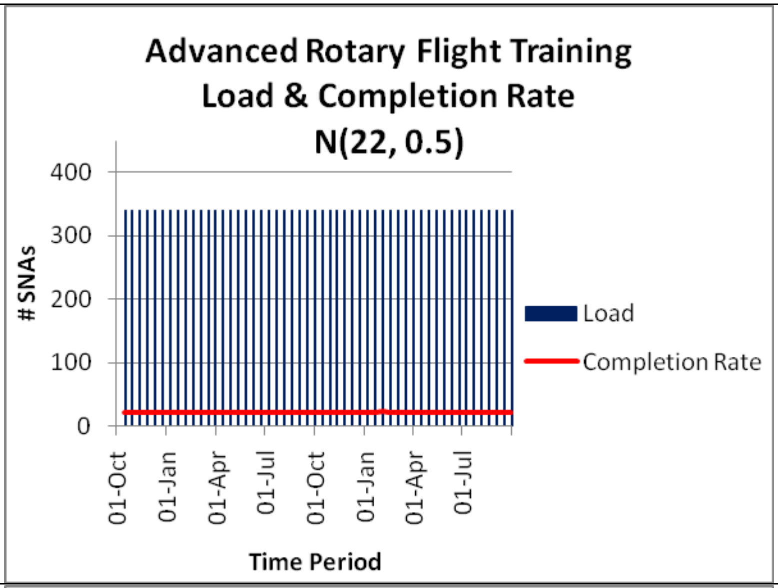

B-Pool Load & Departure Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
01-Apr
01-Jul
Time Period
Load
Departure Rate

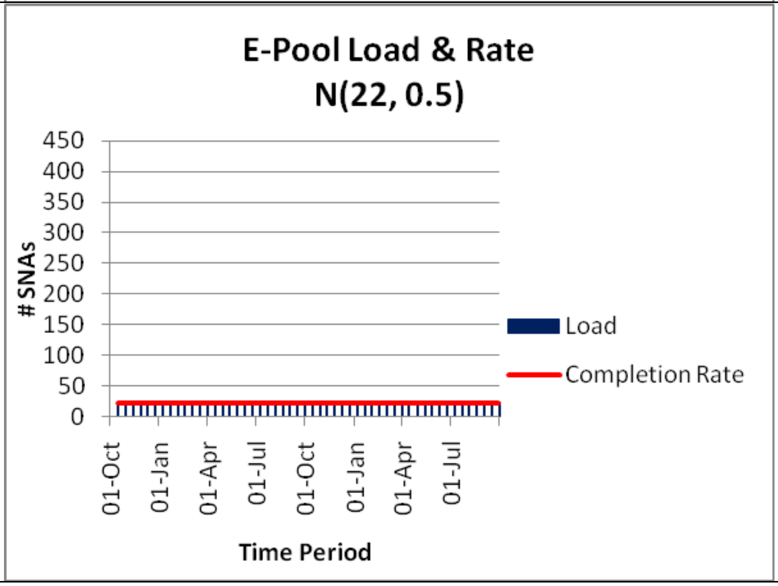

API Load & Completion Rate
N(22, 0.5)
# SNAs
400
300
200
100
0
01-Oct
01-Oct
Time Period
Load
Departure Rate

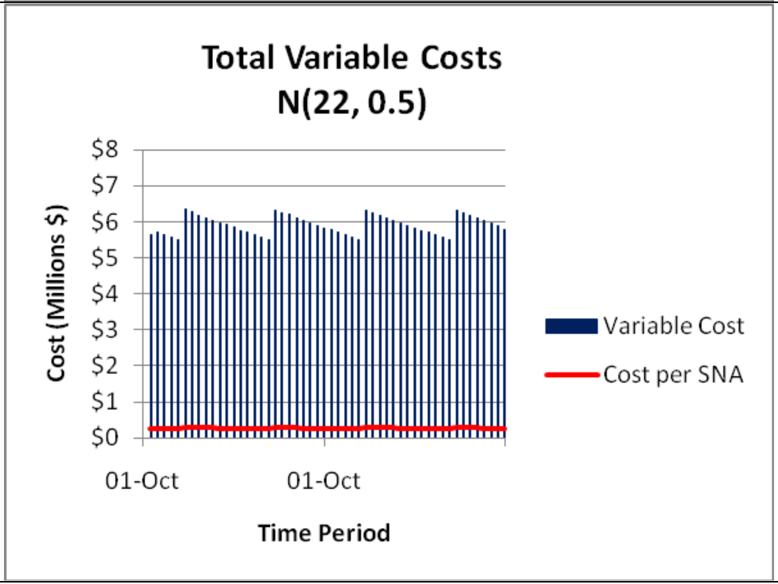

C-Pool Load & Departure Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Oct
Time Period
Load
Departure Rate


Primary Flight Training
Load & Completion Rate
N(22, 0.5)
# SNAs
400
300
200
100
0
01-Oct
01-Oct
Time Period
Load
Completion Rate


D-Pool Load & Departure Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
01-Apr
01-Jul
Time Period
Load
Completion Rate


Advanced Rotary Flight Training
Load & Completion Rate
N(22, 0.5)
# SNAs
400
300
200
100
0
01-Oct
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
01-Apr
01-Jul
Time Period
Load
Completion Rate


E-Pool Load & Rate
N(22, 0.5)
# SNAs
450
400
350
300
250
200
150
100
50
0
01-Oct
01-Jan
01-Apr
01-Jul
01-Oct
01-Jan
01-Apr
01-Jul
Time Period
Load
Completion Rate


Total Variable Costs
N(22, 0.5)
Cost (Millions $)
$8
$7
$6
$5
$4
$3
$2
$1
$0
01-Oct
01-Oct
Time Period
Variable Cost
Cost per SNA

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